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Research on improving maritime emergency management based on AI and VR in Tianjin Port

Shuli Sun

WORLD MARITIME UNIVERSITY
Dalian, China

RESEARCH ON IMPROVING MARITIME EMERGENCY MANAGEMENT BASED ON AI AND VR IN TIANJIN PORT

By

Sun Shuli
The People's Republic of China

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In

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DECLARATION

I certify that all the material in this dissertation that are not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

Signature:

Date:

Supervised by: Associate Professor Zhao Jian

Dalian Maritime University

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ABSTRACT

Title of Dissertation: **Research on Improving Maritime Emergency Management Based on AI and VR in Tianjin Port**

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Tianjin Port is the largest port in northern China, which will become more prominent as a maritime hub with the development of China's strength in transportation strategy. Maritime search and rescue is not only a crucial means to ensure the safety of ships and personnel, but also an important public welfare undertaken by the Chinese government. The quality of emergency management not only reflects the governance capacity of the maritime and port authorities, but also represents the level of economic and social development. Tianjin Port is located in the western part of the Bohai Sea, with a wide search and rescue area, densely distributed ships, and many offshore oil rigs. The risks of ship collision and offshore oil spills have always been high.

This paper reviewed the evolution of China's emergency management strategy, described the current situation of maritime emergency management in Tianjin, and analyzed the outstanding problems in current emergency management, such as the weakness of regional coordination and cooperation capabilities, the insufficiency of the methods of maritime cruise supervision and the expensiveness of the emergency drills. This paper introduces the development and application scenarios of AI and VR so as to apply the technical advantages of AI to break through the bottlenecks in emergency management. The AI equipment introduced, such as unmanned ships, drones, and intelligent robots to enhance maritime patrol and on-site rescue capabilities. AI technology paths such as big data, image recognition, and in-depth algorithms to improve early warning efficiency and emergency decision-making capabilities were applied where necessarily; it uses VR technology to improve participants for taking the role of emergency search and rescue coordinators and their abilities in on-site rescue by simulating emergency search and rescue scenarios, which makes emergency drills more realistic. Finally, combined with some actual cases, it proves the feasibility of AI and VR application scenarios in emergency management. At the same time, in order to ensure the smooth application of new technologies in emergency management, this research also puts forward suggestions for the improvement of Tianjin's maritime emergency management system.

KEY WORDS: Maritime Emergency Management; AI; VR; Search and Rescue

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LIST OF ABBREVIATIONS

AR	Augmented Reality
AI	Artificial Intelligence
ANN	Artificial Neural Network
AIS	Automatic Identification System
CCTV	Closed Circuit Television Camera
CRS	China Rescue & Salvage
CEM	Comprehensive Emergency Management
DL	Deep Learning
DSS	Decision Support Systems
IoT	Internet of Things
IEMIS	Integrated Emergency Management Information System
MSA	Maritime Safety Administration
M.V	Motor Vessel
ML	Machine Learning
MRCC	Maritime Rescue Co-ordination Center
SRR	Search and Rescue Region
SAR	Search and Rescue
TEU	Twenty-foot Equivalent Unit
UAV	Unmanned Aerial Vehicle
VR	Virtual Reality
VLCC	Very Large Crude Carrier
VTS	Vessel Traffic Service

CHAPTER 1 INTRODUCTION

1.1 Background of the research

As the cheapest transportation route in the world today, shipping industry is responsible for more than 90% of the world's cargo transportation (Li, Yin & Fan, 2014). In China, current maritime transportation systems are an integral part of the infrastructure systems. The maritime transportation system in China requires big investment on parts of the governmental entities and taxpayers (Kasim, 2017). Tianjin Port is an important port in northern China, located at the western end of Bohai Bay. According to the Statistics of the World Shipping Council, Tianjin port ranked among the top 10 ports in cargo throughput in recent five years. In 2019, Tianjin port ranked the ninth in the List of global container ports published by Lloyd's Daily. Qinhuangdao Port, Dalian Port, and Yantai Port are all located around Tianjin Port in the Bohai Sea, forming a complete and robust shipping industry chain. With the rapid development of the shipping industry in the Beijing-Tianjin-Hebei region, an increase can be seen in the shipping traffic between Tianjin and Hebei ports and that among Tianjin and international ports. Thus, there are more and larger ships and VLCC in the waters of the Bohai Bay. It brings the following problems: some fishing vessels operate illegally in merchant shipping routes and anchorages; the conventional navigation routes are heavily intertwined; the densities of navigating ships and oil rigs are high; the risks of ship accidents and oil spills at sea are surging and so on.

Tianjin Port is a first-class deep-water port in the world. Its throughput ranks among the highest in the world, with a complete range of cargoes, including bulk cargos, general cargo, container, and liquid chemical. It can provide cargo shipping services for Tianjin and nearby areas, as well as landlocked countries such as Mongolia. It has shipping links with more than 600 ports in more than 180 countries and regions in the world. Table.1 shows the cargo handling capacity of Tianjin Port in recent years.

Table 1: The cargo handling capacity of Tianjin Port in the past ten years

Year	handling capacity (10,000 tons)	Container throughput (10,000 TEU)
2011	45325	1150
2012	47600	1230
2013	50000	1300
2014	54002	1400
2015	54051	1411
2016	55000	1450
2017	50284	1504
2018	44604	1601
2019	49220	1730

Source: Tianjin port

Table 2: The SAR data of Tianjin in the past five years

Year	**Number of operations**	**Number of ships rescued**	**Number of people rescued**	**Rate of success**
2015	24	21	210	97.67%
2016	35	32	319	97.26%
2017	27	24	220	99.10%
2018	37	34	376	97.92%
2019	39	33	359	97.55%

Source: Tianjin MSA

Table 2 illustrates the SAR data of Tianjin in the past five years. Marine emergency has a great impact on the environment, human being and economy. The following cases are typical accident cases in Tianjin sea area. Figure 1 shows a scene of serious collision, in which the largest container ship in the world, M.V. MSC JOANNA, collided with the largest dredger, M.V. WD FAIRWAY, in the waters north of the main channel of Tianjin Port on March 8, 2007, leaving 42 crew members in distress. In June 2011, M.T. Penglai 19-3 crude oil spill polluted more than 6200 square kilometers of Bohai Sea. On December 8, 2013, Cambodian general cargo ship “MARK1”resulted in a fire when conducting electric welding during berthing, which caused the over burning of the bridge and the direct economic loss of 1 million RMB. On January 21,2016, Tianjin met its lowest temperature,-19℃, in a decade, and there was a large amount of ice on the sea surface. Four fishing boats were trapped on the sea and could not move. The Tianjin MRCC deployed several icebreakers and rescued all the trapped ships after more than 10 hours. In February 2018, an unknown ship capsized at the anchorage of Tianjin Port, causing eight crew members missing. While the shipping industry promotes the rapid development of economy, relevant marine accidents and oil spills also cause casualties, economic losses and severely damage the marine environment. More and more citizens are aware of the importance of the shipping economy and pay more attention to the shipping safety. It will be increasingly important to ensure the safety and stability of the shipping market.

Figure 1: Scene of M.V. MSC JOANNA collided with M.V. WD FAIRWAY
Source: Tianjin MSA

1.2 Objectives of the research

The primary objective of this thesis is to research and apply cutting-edge technologies to solve the problems faced by Tianjin Port in term of search and rescue emergency management. Based on the whole process emergency management model, the technical advantages of AI in emergency cruises, rescue decision-making, on-site search and public opinion guidance to enhance the maritime emergency management capability. At the same time, VR technology was advocated to apply for the authenticity and controllability of emergency drills.

1.3 Methodology of the research

This paper applies a variety of research methods, including literature review, model analysis, and qualitative analysis and case analysis. Literature was widely reviewed in this paper including IMO documents, China's regulations, previous research papers, books and articles from journals, libraries of DMU and WMU, and Internet websites. Model analysis adopts the current mainstream models of PADM and NEIM to analyze the emergency management process, and builds a Whole Process Model of emergency management. Qualitative analysis focuses on the feasibility study of AI technology in maritime emergency, summarizing the development of AI technology and the update of emergency assistance strategies and technologies so as to put forward reasonable suggestions based on challenges. The case analysis of the successful application of AI equipment in Tianjin Port in recent years has confirmed the feasibility of the research objectives of this paper.

1.4 Structure of the dissertation

This research paper consists of 7 chapters. Chapter one provided background information, objectives and methodologies to be used. Chapter two widely reviewed the development status of AI and VR technologies and their application scenarios in emergency management. Chapter three concerned a Whole Process Model of emergency management, analyzed the application and challenges of emergency decision-making system. Chapter four summarized the risk factors and development dilemmas of search and rescue emergency management in Tianjin Port. Chapter five discoursed proposals, in which AI and VR technologies were introduced in Preparation, Process and Recovery stages to improve emergency management capabilities. Chapter six demonstrated two application cases of AI equipment in marine emergency. The last chapter was the conclusion and summary including the limitation of the study and outlook for further researches.

CHAPTER 2 Development and Application of Artificial Intelligence and Virtual Reality

2.1 Literature review of Artificial Intelligence

Artificial Intelligence (AI) was first proposed by the American Dr. John McCarthy at the Dartmouth Conference in 1956, and has experienced many developments and stagnations (Ramesh, Kambhampati & Monson, 2004). The definition of Artificial Intelligence usually refers to the simulation of human intelligence processes by machines. Human-like capabilities enable robots to replace humans in the process of intelligent behavior including cognition, recognition, analysis, and decision-making. Artificial Intelligence is a branch of computer science. It attempts to understand the essence of intelligence and produce a new intelligent machine that can react in a similar way to human intelligence（Greenhill, 2019）. Research in this field includes machine learning, language recognition, image recognition and expert systems.

Figure 2 intuitively reflects the process of AI through its value chain AI. Information enters from the underlying infrastructure, to the software technology layer for further analyze and assessment, and then to the application layer, where the complete information is processed in the form of products through different application scenarios shown in front of users.

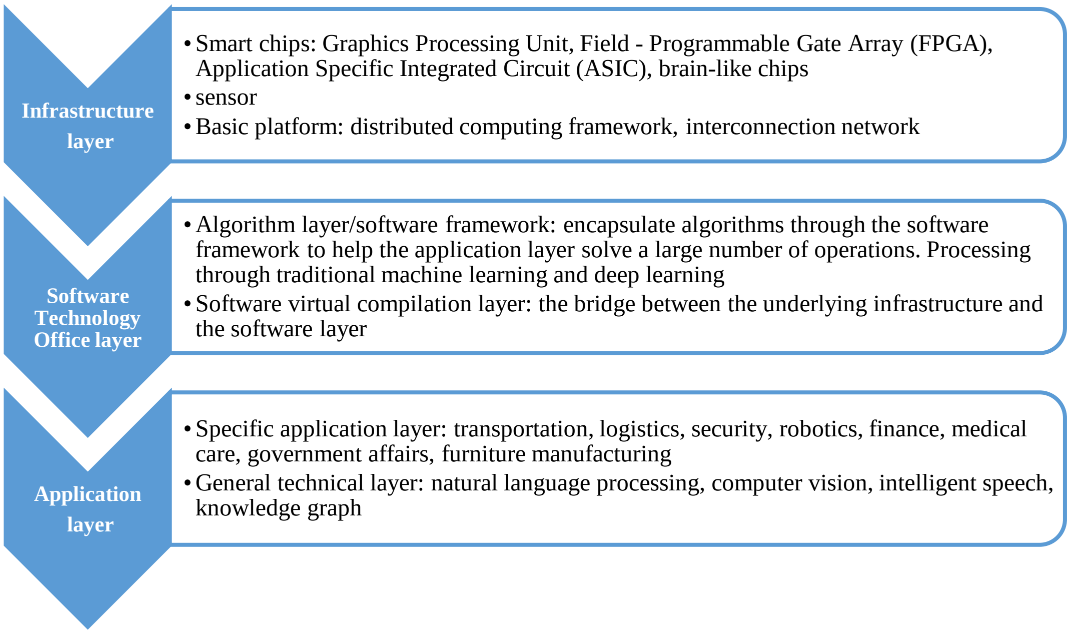

Figure 2: The value chain of the artificial intelligence

Source: compiled by author

Application layer: For example, in the value chain figure, the industry application of AI requires basic computing power, algorithms, industry big data, as well as the understanding of the scene. The most direct and significant performance of AI is to replace artificial labor and improve business efficiency. In addition by replacing the repetitive and dangerous tasks that can be done by traditional automation, the learning ability of AI technology can solve some complex, professional, and flexible tasks. For instance, through AI technology, auditors can quickly achieve a comprehensive review of corporate bills instead of spending vast time only acquiring sample surveys. Another important application scenario of AI is the intelligent support for management decision-making. Managers can rely on the suggestions provided by the AI system to assist the decision-making process with data-driven simulation calculations. For example, marketing management is one of the current typical cases. AI realizes the accurate depiction of user portraits. It relies on multiple heterogeneous data joint modeling to realize precise marketing placement and personalized advertising flow. In the future, intelligent machine assistants and consultants will become standard equipment for managers. Moreover, the application of AI technology will also bring new changes to the corporate management structure by rebuilding the management structure and creating a new cooperation model in order to operate the organization more efficiently.

2.2 Literature review of Virtual Reality

In the 1980s, the concept of virtual reality (VR) was formally proposed. In August 2012, the VR devices launched by Oculus began to gain the attention of ordinary consumers. In 2019, the VR industry has made significant progress in software and hardware, content development, and application services. The introduction of 5G system-on-chip (SoC), breakthroughs in display resolution and time delay, improvement of wireless problems and interaction methods have improved the pain points on dizziness, portability and interactivity. VR technology is maturing, with increasingly realistic simulation of vision, force, touch and other senses, allowing users to perform in a virtual scene in a timely and unlimited manner.

VR technology refers to the use of the computing power to generate an immersive, user-interactive virtual scene. Users wear related VR equipment to interact autonomously with the objects in the virtual scene, which makes them feel immersive through multiple perception methods. The realization process of VR is that the examiner operates in the virtual environment to obtain real-time three-dimensional display, and then collects feedback information such as touch and force through the sensing device.

VR technology mainly includes simulated environment, perception, natural skills and sensing equipment. The simulated environment refers to dynamic three-dimensional and realistic images generated by computers in real time (Ding, et al., 2020). Perception means that the ideal VR should have everything that human could perceive. In addition to the visual perception generated by computer graphics technology, there are also senses of hearing, touch, force, movement, and even smell and taste, which are known as multiple perceptions. Natural skills refer to that the head turning, eye rolling, gestures or other physical actions of human beings are processed by the computer to form input data and feedback to the VR system (Zhou, 2020). Sensing equipment refers to three-dimensional interactive equipment.

2.3 Other related technologies

Big data technology is a new generation technology of architecture data, which can immediately process and purify all kinds of complex data, and extract the rule of the nature and comprehensive knowledge of human society. The sources of big data include nature, life and biology and society.

Big data technology is the cornerstone of the development of AI. The application scenarios of AI are to integrate a large number of data resources, build a database model, and use algorithms to achieve the purpose of intelligence. With the popularization of the IoT, more and more data resources will be connected to the

Internet, which will further promote the development of AI.

At present, the technical applications of AI are mainly concentrated in the following areas. Natural language processing: through language modeling, machine translation, language synthesis to achieve barrier-free communication between human and computers. Computer vision: through image classification, target recognition, target tracking, to simulate the human visual system and obtain the ability to recognize and understand images. Knowledge graph: through the association of knowledge nodes and relationships, to make AI closer to human cognitive thinking.

2.4 Application of Artificial Intelligence and Virtual Reality

The initial stage of AI is composed of a series of preset code instructions. After more than 50 years of development, AI has been able to execute complex algorithms similar to the human brain. Machine learning (ML) is to optimize computer programs with data or prior experience. Using this tool, you can dynamically formulate a rescue plan based on the data of the emergency rescue site, instead of following the previous static rescue decision. Now deep learning (DL) is developed from machine learning. That is to create an artificial neural network (ANN), learn the internal laws and representation levels of sample data, and then make decisions thinking like a human brain (LeBerre, Sandborn & Aridhi, 2020). Artificial intelligence is to simulate certain human intelligent behaviors by establishing databases and models. AI application can actively promote the development of productivity and increase per capita disposable property and overall employment. The AI revolution is a challenge in the context of globalization. People began to transform their perspectives into AI technology in the field of emergency management.

Without direct human interface, various types of natural processes and catastrophes are monitored or participated by AI robots, which signifies the robots' engagements especially in hazardous situations such as fires in forest (Srinivasan et al., 2012), pollution on the ocean's surface (Ma et al., 2017a), oil spill and radioactive wastes (Aznar et al., 2014), and geologists such as (Bogue, 2011) engaged mobile sensors to survey the volcanic behaviors.

Currently, VR technology has achieved many successful cases in the research and development of media and entertainment, teaching, sports, industrial simulation, medical and other fields. The enhancement or reconstruction of the scene is more perceptual, interactive, autonomous, and existent than previous information-based applications. It will overturn the existing perception and experience and will revolutionize the future.

For example, in the military field, VR technology is used in the construction of virtual battlefield systems, which gradually transforms military combat training to a new type of combat model that is intelligent, information-based, and global. In sports simulation, VR technology is used in the virtual training of dangerous and complex projects, such as racing, skiing, rock climbing, etc. In the entertainment industry, the popularity of VR games has led to the vigorous development of VR technology. Many technology companies have recently launched virtual game products using the latest VR devices, such as Forza Motorsport and NI virtual game consoles.

The G-Magic Virtual Reality Laboratory of East China University of Science and Technology is an example of VR teaching in universities. The laboratory has a cave-like VR system, which can project the works designed by students on the walls, ceiling and ground. For example, a student designed a shower room, he can use the VR system to show it in the laboratory, having the same size as the actual one. In this scenario, teachers and students can better communicate the pros and cons of each link of the design, and make changes at any time.

2.5 AI and VR application scenarios in ports

According to a survey conducted by the International Maritime Information Network on automated ports, nearly 75% of port operators believe that automation is essential for port development; nearly 65% believe that automated port operations can improve operational safety; 33 % of respondents believe that automated ports can increase port production efficiency by 50%, and another 20% believe that the construction of automated ports can reduce operating costs by more than 50%.

The Chinese government work report in 2019 put forward the important strategy of “smart +”, appealing to accelerate the research and development and application of big data, AI, etc., form an industrial Internet evaluation mechanism, and empower the transformation and upgrading of the manufacturing industry. As early as 2017, the Ministry of Transport issued the “Notice on the Development of Smart Port Demonstration Projects”, and selected a number of ports to develop smart port demonstration projects to promote the informatization and intelligentization of domestic ports.

The port is developing from an inter-regional commodity circulation center to a global commerce and shipping industry center, with cargo warehousing, transportation and trade information services, cargo distribution and other diversified services. Taking the intelligent container terminal as an example, traditional and simple calculation programs can no longer meet the demand for the huge amount of data processed by large-scale container terminals. A real-time interactive computer management system that combines optimization algorithms and AI must be used to meet the requirements of container loading and unloading, stacking, receiving and dispatching and other operations. In the future, the port will become a logistics hub that integrates transportation center, data center, and service center to promote the optimal allocation of resources in cross-industry, cross-department, and cross-regional.

When it comes to the AI applied in the ship transportation system, the Singapore Port is a good example. The Port of Singapore is committed to building a new AI ship management system based on machine learning. This system can help ports predict the short-term trajectory of ships in the ocean, and predict the long-term navigation conditions of ships based on ship types and historical data. In addition, the system can also integrate various risk models and hotspot models to quantify the risk of ship loss, and provide an intelligent coordination model to avoid ship collisions. The use of AI technology to break through the barriers in the logistics chain will promote the efficient operation of port logistics, information flow, and capital flow, and provide better services for cargo owners, logistics companies, shipping companies, government departments, financial institutions and other entities.

2.5.1 AI application scenarios in addressing the risk of collision in port

Most vessels currently rely on manual lookouts to reduce the risk of collision. This creates unlimited opportunities for error and often means that ships' pilots, surveillance personnel and captains do not have adequate warning time to avoid collisions.

Figure 3 shows Fujitsu has developed an artificial intelligence (AI) solution that can identify the risk of vessel collisions, then deliver warnings up to 15 minutes in advance, giving the crew ample opportunity to take evasive action. It has been successfully tested in the Port of Singapore, one of the world's busiest ports.

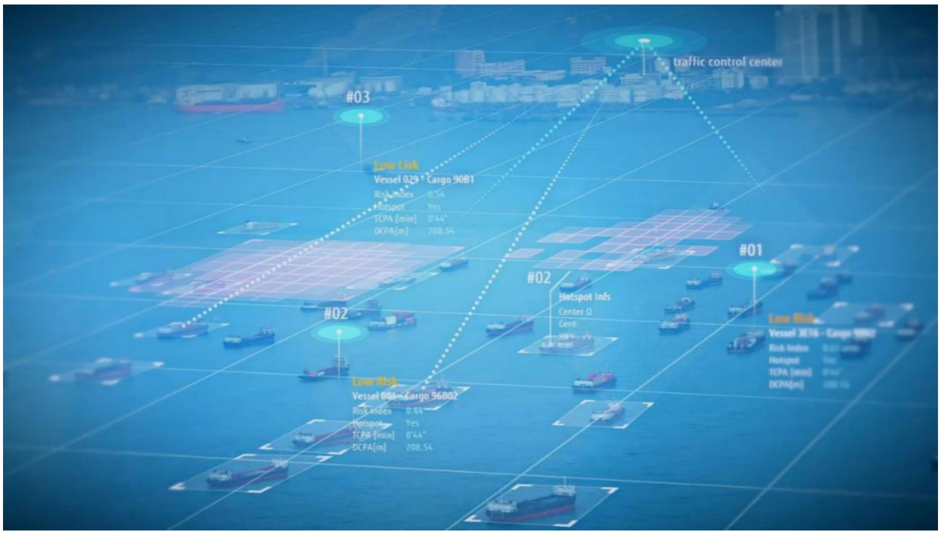

Figure 3: AI solution the risk of vessel collisions

Source: Kenta, 2020

2.5.2 VR application scenarios of emergency rehearsal in ports

Currently, research on Emergency Rehearsal of International Cruise Port Based on VR is underway in China. It is planned to build a virtual simulation platform for the international cruise port and a 3D model of the real scene of the cruise port to reach the interactive function of the cruise port and the safety drill function, and to realize the collaborative participation of multiple VR platforms. Through those platforms, the purpose of school teaching and emergency drills can be completed. On the one hand, they can cultivate students' cognition of cruise port areas, help them master the procedures of boarding and disembarking cruise passengers and inspired them to learn through realistic, interactive and immersive practical exercises. On the other hand, those platforms can help the staff in the cruise port to obtain professional skills and emergency knowledge, including fire emergency response, anti-typhoon evacuation, etc.

2.6 AI and VR in emergency management

In the past, AI was limited by technological development and prevented the acceptance and application in the field of emergency assistance (Amisha & Pathania, 2019). Since 2000, DL algorithms have become popular, laying the foundation for the vigorous development of AI. The increase in computing power brought by chips, supercomputers, and cloud computing, the data explosion and in-depth mining and utilization brought by the IoT and big data technologies and the accumulation of industry talents have promoted AI from the laboratory to the commercialization Scenario application. In particular, industries such as transportation, finance, retail, education, and healthcare have become the forefront of AI applications.

Although the current application of AI is still limited AI which requires human participation and can only solve problems in specific areas, so there is still a long way to go before general AI based on brain-like technology with autonomous learning capabilities in the future. But from the perspective of real development, the construction of a large number of data sets, transfer learning, and small sample learning at the technical level will definitely further promote the development of application fields; at the application level, AI and robotics, big data, cloud computing and the gradual integration of technology applications such as edge computing will further promote the gradual realization of diversified application scenarios.

Normal maritime search and rescue scene cannot be seen the performance of distress monitoring, communication, co-ordination and search and rescue functions, including provision of medical advice, initial medical assistance, or medical evacuation, through the use of public and private resources, including co-operating aircraft, vessels and other craft and installations. As a new type of search and rescue resources such as drones, unmanned ships and other AI equipment, it is intelligent and convenient compared with manned search and rescue ships and aircraft, and is gradually applied to the process of maritime emergency search and rescue with the advantages of high accuracy and low cost.

The introduction of VR technology in the field of maritime emergency search and rescue can effectively enhance emergency personnel's ability to respond to emergencies, improve the efficiency of incident handling, and minimize the social impact of incidents (Mu, & Zhao, 2020).).

Australian search and rescue agencies use training algorithms to distinguish and search for targets that are difficult to find by the human eyes. For example, searching for rescue targets on a wide sea surface can effectively improve the efficiency of SAR operations. The AI camera carried by the drone can cover a wider search area in a short period of time. After their positioning, sending coordinates can save several hours of search time (“Australian Air Force”, 2019).

UAV is a typical scenario of AI application, and has been widely used in various fields such as reconnaissance, surveillance, search and rescue and other fields. On account of the maximum flexibility without the limit of human body functions, UAV shave better mission performance in boring, bad and dangerous conditions, and have obtained amazing achievements in both military and civilian fields. Especially, UAVs are increasingly active at fire monitoring, disaster monitoring, maritime rescue, medical supplies delivery and other disaster relief scenes in current days with frequent natural disasters.

The Tianjin MSA is equipped with UAVs on the maritime patrol ship, which are mainly used for air cruise inspection and maritime search and rescue. However, once an emergency occurs in the waters of Tianjin Port with bad sea conditions and weather and large search and rescue area, it is hard for a single UAV to complete the search and rescue tasks because the UAVs have limited load endurance and low anti-risk ability against severe disasters such as heavy weather (Yang, et al., 2018). Some research institutions propose to use the multiple UAVs to participate in maritime search and rescue, which can make up for the disadvantages of a single UAV, such as small search area and low anti-risk capability. However, the application research of the multi-UAV mission planning system in search and rescue at sea is still inadequate. For example, how to effectively quantify the threat of sea weather to UAV (Bagherian & Alos, 2015), how to add real-time data of the search and rescue scene to the mission management model (Geng, Zhang & Wang, 2013), and how to quickly evaluate the reasonableness of mission planning (Hu, et.al, 2015). These problems have severely restricted the application of UAVs in search and rescue. The great computing power of AI can simulate the thinking mode of human beings to make judgments and instructions immediately, evaluate the best path quickly in a complex environment, and accurately control each UAV to make real-time response by feedback to each one through the mission system.

Figure 4 shows a new type of drone named Roboguard developed by Iranian RTS Ideas Company, which can shorten the time required to reach the target through path optimization, and put the carried lifebuoy on the rescued scene to realize the rescue of multiple drowning targets (Chun, et.al. 2016). The Roboguard body uses waterproof materials to complete take-off and landing operations in the water. Its flying speed can reach 30 kilometers per hour, and it can perform missions within a range of 8 kilometers. It can also carry 15 kg of payload, and perform autonomous rescue missions through its GPS positioning system.

Figure 4: Roboguard UAV with three life preservers

Source: Chun, et.al. 2016

Besides, the main task of emergency management is to deal with marine ship emergency accidents and marine pollution accidents. To a large extent, both events will occur simultaneously. Marine oil spill pollution accidents are classified into operational oil spills and accidental oil spills. In an oil spill, it is necessary to use the oil containment boom to control the sea surface oil, and the oil skimmer to recover it. Since the expansion of offshore oil spills is greatly affected by sea conditions and weather, it is necessary to accurately predict the spread direction and location of oil spills in order to quickly control the spread of offshore oil spills.

In the emergency management, some unidentified marine oil spills are often encountered, which may be caused by the malicious discharge or the illegal operation of the ship. The effective emergency management includes finding the source of these oil spills, penalizing the ships that discharged them, and taking measures to prevent the possibility of oil spills again.

For unidentified oil spills at sea, continuous monitoring of the sea surface environment is required, which needs abundant labor costs. Moreover, once an unknown oil spill is found, it is necessary to expand the search and observation area, and the target attributes of the oil spill are variable in space and time (Wang, 2015). The past detective methods included a series of measurement samples to create a map to visually observe the source of the oil spill (Pashna, et al., 2020). Based on the development of electronics, hardware and communication technology, automation technology could complete this labor-intensive environmental monitoring task. (Wang et al., 2015). Especially, the detection area is expanded and multiple devices and sensors are required to cooperate to complete a task, the multi-agent system (MAS) can solve the coordination and cooperation between multiple devices. In this system, drones, unmanned ships, intelligent robots, etc. can cooperate with each other to reach a consensus goal (Aznar et al., 2014).This multi-agent system requires the distributed control by a powerful central control, which can be supported by the development of AI in the fields of autonomous driving, big data analysis, and deep learning.

CHAPTER 3 Emergency Management System

3.1 Comprehensive emergency management theory

Comprehensive Emergency Management (CEM) was originally proposed by the United States, which supports all stakeholders participating in emergency management, supports the whole process of the emergency management lifecycle, and covers all hazards and impacts in emergency management (Laidlaw, Spennemann & Allan, 2008).

The whole process management is divided into several stages according to the time period during an emergency. Figure 5 illustrates that the four stages include mitigation, preparedness, response, and recovery (Zlatanova & Fabbri, 2009).

Figure 5: Emergency management cycle
Source: Zlatanova & Fabbri, 2009

CEM is a sort of holistic model, especially when considering that this type of management plays a role in guiding public policy and research directions. Through CEM, emergency planning has been practiced and at the same time related researches have been organized (Adams, 2008). According to a review of the literature, the effectiveness of CEM has been proved in many countries, as in the aspect of sustainable emergency planning during earthquakes in Iran in the last 20 years (Hosseini, et al., 2009).

3.2 The Whole Process Model of Emergency Management

According to CEM theory, this paper combines the Protective Action Decision Model (PADM) and the National Economy Integrated Mobilization (NEIM) models to construct a Whole Process Model of Emergency Management, and analyzes the utility changes of the rescue organization government and the individuals of the victims in different marine emergency events. Disasters can be divided into instantaneous disasters and continuous disasters according to their duration.

As is shown in Figure 6, the Protective Action Decision Model (PADM) is a multi-stage model based on the research results of people's response to environmental disasters and accidents. PADM puts the role and requirements of risk perception and risk communication in the pre-disaster stage. It is recommended that "individuals" choose appropriate social clues and resources for different types of disasters, so as to improve risk perception and make protective action decisions; at the same time guide relevant government departments to choose effective information dissemination methods to improve "individual" disaster knowledge and prevention awareness (Huang, Lindell & Prater, 2017).

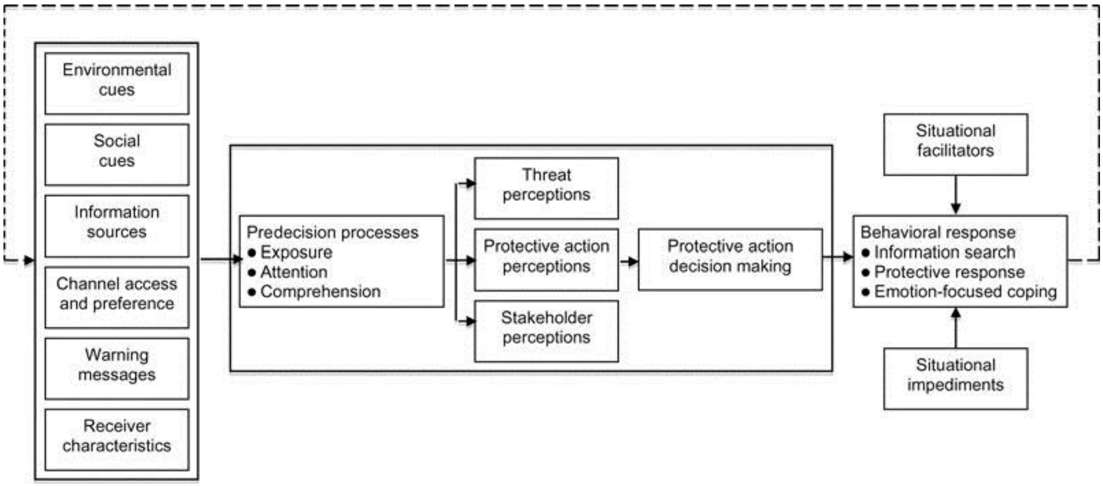

Figure 6: Information flow in the PADM

Source: Adapted from Lindell & Perry, 2004

The goal of National Economy Integrated Mobilization (NEIM) is to respond to specific emergency needs and quickly provide resource guarantees for responding to wars or emergencies. As is shown in Figure 7, integrated mobilization takes the national economic mobilization chain as the main line, takes the actors required to complete the mobilization task as the interface, selects different executive bodies, and builds a mobilization alliance (Kong & Han, 2015). Under the unified command of the highest coordination department, the integrated mobilization coordinated various actors in accordance with the required time and steps, saving mobilization time and cost, and improving mobilization efficiency (Kong, 2012).

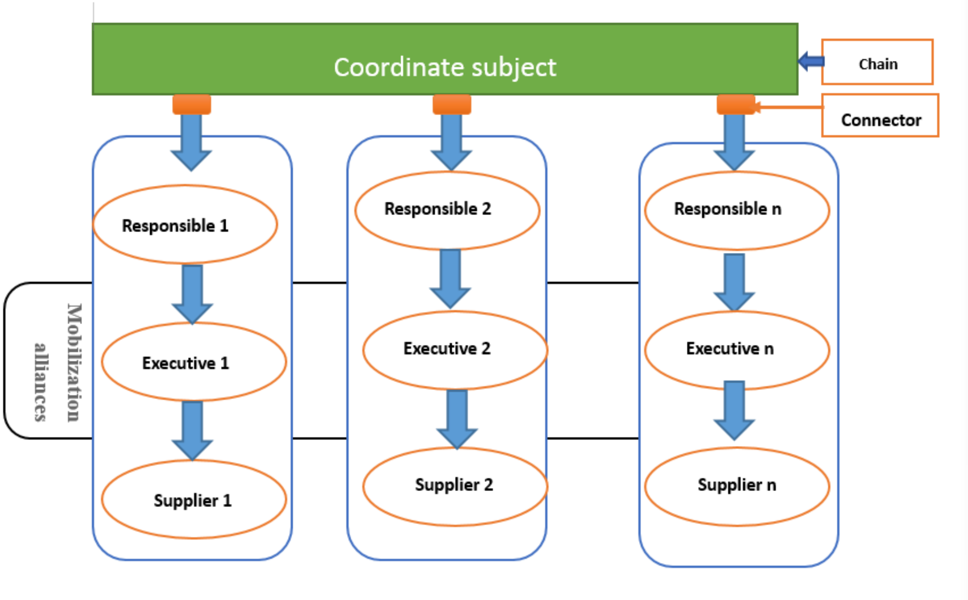

Figure 7: The NEIM model

Source: Adapted from Kong & Han, 2015

The goal of emergency management is to allocate resources reasonably according to time requirements, which not only provides information needed by "individuals" before disasters to improve their risk perception and response capabilities, but also provides information for decision-making by governments. Moreover, emergency management provides rescue resources during disasters to reduce casualties and property losses, and supplies food, accommodation, and medical resources to help individuals after disasters. The outstanding feature of integrated mobilization is to complete the required tasks, coordinated with the appropriate subjects at the accurate time. Therefore, the integrated mobilization strategy provides another perspective for emergency management.

Combining the theory of PADM and NEIM, Figure 8 shows the corresponding relationship between the Whole Process Model of Emergency Management and the emergency process.

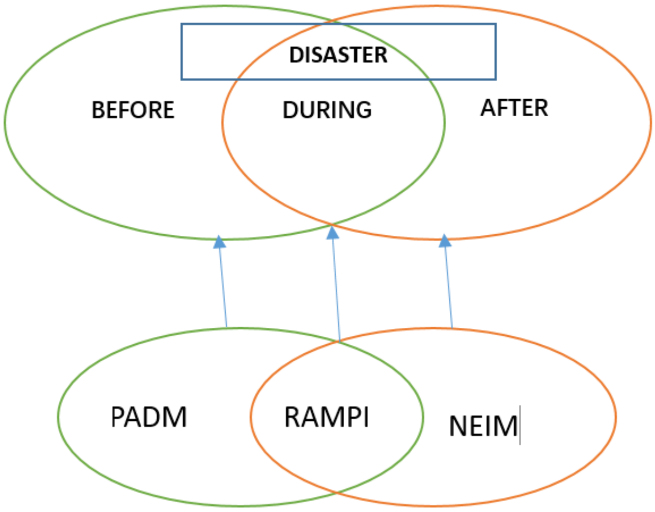

Figure 8: The relationship between Whole Process Model and disaster

Source: Compiled by author

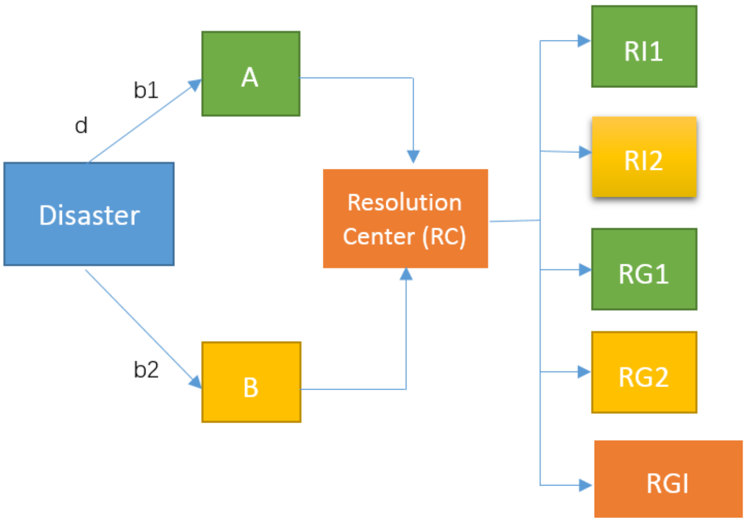

Figure 9: The response action and mobilization plan implementation model

Source: Adapted from Liu, Kong & Zhang, 2019

Figure 9 illustrates the response action and mobilization plan implementation model (RC) during the disaster process.

In the model, "*d*" represents marine emergency events, "*b1*" and "*b2*" on behalf of the type identification of disasters, "*A*" delegates instantaneous disasters, and "*B*" represents continuous disasters. Continuous disasters are easier to predict, so the probability of successful disaster identification P (A) <P (B); Individuals and governments apply PADM and NEIM strategies to respond to different disasters. According to the effect and impact of different disaster types, individual responses are RI1 and RI2, and government response measures are RG1 and RG2, the response strategy of cooperation is RGI. Among them, the probability of PADM having an effect on *A* disasters is p (P1), and the probability of "individuals" take RI1 action is p (RI1); the probability of PADM having an effect on B disasters is p (P2), and this effect makes the probability of "individual" making RI2 is p (RI2). The probability of NEIM's effect on Category A disaster is p (N1) (approximately equal to 0), and this effect makes the probability of government making GI1 is p (GI1) (approximately equal to 0); the probability of NEIM's effect on category B disasters is p (N2), and this effect makes the probability of government making RG2 is p (RG2). After analysis, it can be seen that NEIM has almost zero effect on instantaneous disasters, so RGI is mainly for continuous disasters. The probability of PADM and NEIM's effect on B disasters is p (PN) = p (P2) × p (N2), this effect makes the probability of both "individuals" and government making RGI is p (RGI) = p (RI2) × p (RG2).

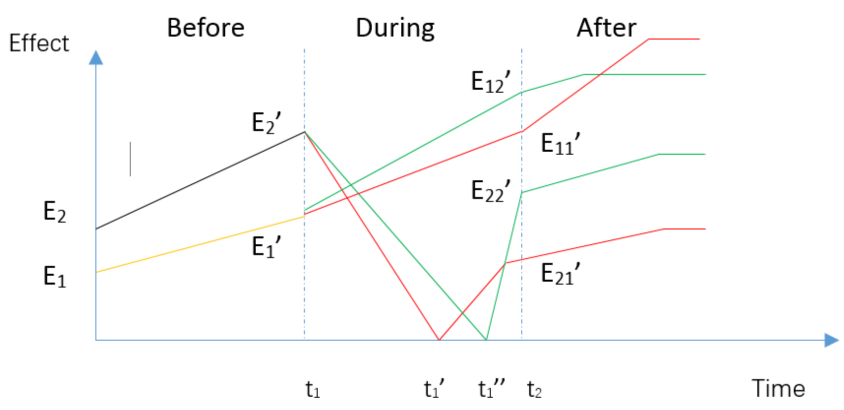

Figure 10: The whole process model of emergency management

Source: Adapted from Liu, Kong & Zhang, 2019

Figure 10 explains the whole process model of emergency management. "t1" represents the time when the disaster occurs, and "t2"refers to the time when the disaster ends. The entire emergency management process can be divided into three stages: before the disaster, during the disaster, and after the disaster. The yellow line represents the government, and the black line stands for the individual. At t1, the utility reaches E1' and E2' respectively, and the increase of the individual is greater than that of the government (Liu, Kong & Zhang, 2019).

In the mid-stage of the disaster, the red line represents the response to transient disasters, and the green line represents the response to persistent disasters. At time t'1, the utility of "individuals" suffering from transient disasters is reduced to 0; at time t"1, the effect of individuals suffering from continuous disasters is reduced to 0, and individuals need "government rescue" when they encounter disasters. The government's effectiveness in facing disasters continues to grow. At t2, the government's utility value on the two types of disasters reaches E11' and E12' respectively, and E12'> E11'> E1'. As the government's utility increases, individuals will recover their utility after a disaster. In the process of disaster handling, the government's utility is stronger than individuals' are, and the government's utility for continuous disasters is better than that for instantaneous disasters.

In the post-disaster stage, the utility of the government and individuals continues to recover, and the utility value remains stable after reaching a certain value. Different from the mid-stage of disasters, the government's recovery utility for instantaneous disasters grows faster than sustained disasters.

3.3 Emergency management system in China

Emergency management is a kind of system design, which is the response of social governance capabilities in the context of emergencies. Generally, emergency management includes three main bodies: government departments, markets and social organizations (including non-governmental organizations and non-profit organizations). As the main provider of emergency management, the government needs to assume the primary responsibility. After the "Haiti Earthquake" in 2010, the Haitian government was nearly paralyzed. The emergency response and post-disaster recovery were mainly led by the United Nations and the NGOs, which shows the chaos and inefficiency of emergency management under anarchy.

The construction of Chinese emergency management system began with the "SARS" epidemic. The current “one case, three systems” inherited and summarized the comprehensive management strategy, emphasizing full disaster management, full process management and multi-agent participation.

In 2007, “Emergency Response Law of the People’s Republic of China” was enacted. This law introduced “All-hazard approach”, named all types of disasters as emergencies, regulated that the governments should uniformly respond to emergencies at all levels, established an Integrated Emergency Management Information System (IEMIS), and established an emergency management office on the basis of the original government duty room. Consequently, China formalized an emergency management model including prevention and preparation, monitoring and early warning, rescue and disposal, aftermath and recovery.

As is shown in figure 11, the inter-ministerial joint meeting of the National Maritime Search and Rescue is in charge of China’s maritime search and rescue work, which is composed of relevant ministries and commissions of the State Council and relevant military departments. The China Maritime Search and Rescue Center, as its office, is responsible for the early warning and prevention of maritime emergencies, life rescue, environmental rescue, and property rescue, clearing of obstacles in important navigable waters as well as receiving and processing of piracy incident information.

Figure 11: Organization of China's maritime SAR system

Source: Ministry of transport of the PRC

China's maritime search and rescue force is mainly composed of professional rescue forces, the military, relevant departments directly under the central government and local departments, as well as various ports, enterprises and institutions, and a large number of merchant ships and fishing vessels sailing in Chinese waters. Professional assistance is mainly provided by the China Rescue & Salvage (CRS), which has three rescue bureaus in the North Sea, East China Sea and South China Sea, three salvage bureaus in Yantai, Shanghai and Guangzhou respectively.

At present, China has formed an emergency management framework based on the model of "one plan, three systems" (an emergency plan and an emergency management setup, emergency mechanism, and emergency legal system). Among them, the emergency management setup concerns on the scale of the government structure, and the emergency mechanism belongs to the scale of the operating mechanism. Emergency legal system is mainly manifested in emergency legislation and emergency response plans (Zhang, & Tong, 2016). On August 7, 2005, the State Council issued the “National Emergency Response Plan for Public Emergencies”, and Law of the PRC on Emergency Response adopted in 2007, which stipulated emergency responses according to the different levels of government. The central, provincial, municipal and county governments are responsible for managing Levels I, II, III and IV of the emergency response respectively. Emergency management legislation has only been taken seriously in the past 20 years. In China, we have adopted the strategy of “response plans first, legislation second”, considering that it takes a long time to complete legislation. The problem of insufficient legal basis for emergency management has been solved in a short time, and the efficiency of emergency management has been improved. However, some problems have also been exposed. For example, due to insufficient legislation, a large number of special plans have been simplified into departmental plans, which are lack of coordination. In addition, the lack of legislative practice foundation, the large number of emergency plans, and the chaotic system structure make it difficult to be effectively apply many emergency plans.

3.4 The principle of SAR assistant decision-making system

The IAMSAR manual (1999, p.171) states that:

> *“Determining the best way to allocate the available search effort can involve a considerable amount of computation. The same is true for determining probability maps for new datum lines or areas when there are significant*

variations in winds and currents. The number and accuracy of the computations which can be done by the search planner without a computer are necessarily quite limited."

In order to find the most effective search and rescue plan, the search and rescue assistant decision-making system needs to simulate the thinking logic of the search and rescue coordinator when dealing with emergency situations (IMO, 2004). It is necessary to develop a multi-level mathematical operation model to analyze the relationship between search and rescue success rate and investment, and investigate the mobilization of appropriate numbers and types of search and rescue resources in different types of search and rescue operations (Wu et al., 2018). It is usually divided into three levels. The first level analyzes various factors that affect the search and rescue process, mainly including the state of the search and rescue target, predicts the change of the search and rescue environment, and investigates the distribution of surrounding search and rescue resources. The second layer is to evaluate search and rescue operations based on the principles of search and rescue plans, select suitable search and rescue resources, formulate task allocation tables, and calculate important search and rescue parameters, such as probability of detection, containment and probability map. The third layer is to compare different search and rescue plans to choose the best plan. Different search and rescue coordinators will think about the same search and rescue mission from different perspectives. Some will focus on search and rescue efficiency, and some will pay more attention to rescue costs, such as the safety of rescue personnel (Xiong, Gelder & Yang, 2020).

In search and rescue response, time is always pressing and tasks are complex. Search and rescue resources need to be organized efficiently and reasonably in advance to mobilize search and rescue resources in the first time. The performance parameters of search and rescue resources are an important basis for measuring the ability of the resources. Usually we need to consider factors such as the type, the location, the number and the wind resistance level of the search and rescue resources.

The formulation of search and rescue plans and the assignment of search and rescue tasks largely depend on the marine environmental factors at that time. Wave height, wind, current, and temperature in a specified location will not only change the state of the search and rescue target but also image the efficiency of search and rescue resources. The status of the search and rescue target while waiting for rescue (life raft, life vest) determines its survival time.

At the same time, useful information about search and rescue dangers is usually not complete, and there may be deviations by misleading. To make up for these shortcomings, search planners must speculate about possible events during the period of time before finding the last known safe location of the survivor. This distress inference must be consistent with known facts. When there are many possible situations, the search and rescue planners need to choose the most realistic one to search. If any information is added, it needs to modify, discard or make new distress judgments. Making such inferences requires professional experience, knowledge, and skills. Large-scale AI that can simulate human thinking is an important part of assisting in the development of search and rescue plans and suggesting possible options.

3.5 Application of SAR decision support systems

In foreign countries, search planning decision support systems (DSS) has undergone several versions (Vidan et al., 2016). The U.S Coast Guard's Search and Rescue Optimal Planning System (SAROPS) first applied in 2003 (Kratzke et al., 2010). Many other research institutions focus on the development of risk identification and safety management decisions to improve maritime traffic safety management（Banda & Goerlandt, 2018）.

MOTHY is a 3D pollutant drift simulation system established by the French Meteorological Agency. The system has been used to predict oil spill drift of oil spill pollution events such as Erika and Prestige (Guo & Mao, 2010). Another search and rescue assistant software that is widely used is SARIS developed by British BMT Company. This software combines the rescue experience of the British Coast Guard and the knowledge of the marine environment professional prediction field, which can help save lives and reduce shipwreck losses. As is shown in Figure 12, SARIS has built-in world-wide tide and ocean current data charts, supporting weather data import and modeling of weather parameters. SARIS can call weather data in the system to predict the movement trajectory and the SAR targets under the combined action of wind, tide and current, to establish the most likely search area based on probability, error and statistical deviation range (Chassingnet & Verron, 2006).

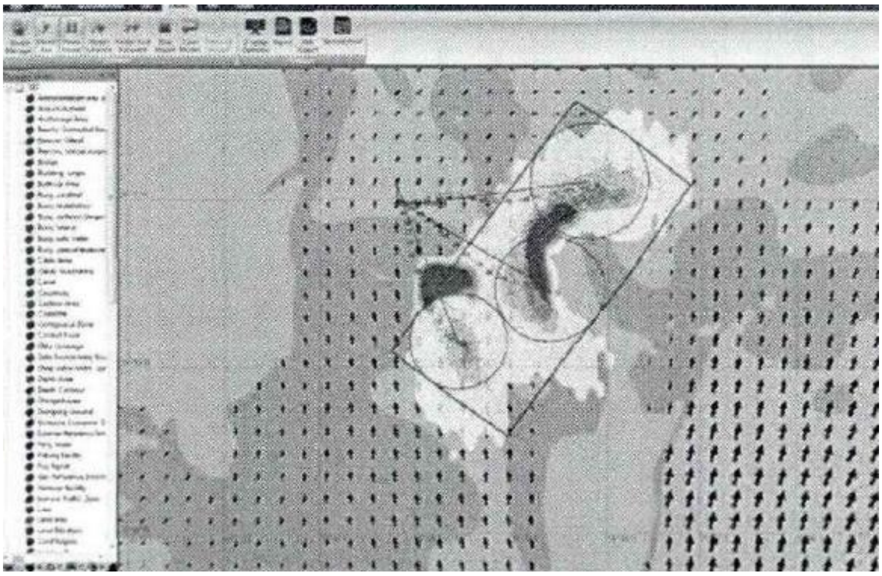

Figure 12: SARIS operation interface

Source: Chassingnet & Verron, 2006

In China, in order to reduce the risk of collisions between ships and bridges, research institutions have designed a ship-bridge collision warning system based on fuzzy logic, which can took a resilience-modulated risk model to the analysis of the disaster accidents to effectively improve emergency response capabilities (Wu et al., 2019).

As is shown in Figure 13, the National Maritime Search and Rescue Support System (NMSARSS) has developed by the State Oceanic Administration, which integrates multiple modules including drift prediction, marine environmental forecasting visualization and collaborative service, aiming to reduce the emergency response time and improve the prediction accuracy of maritime SAR (GAO, et al., 2019).

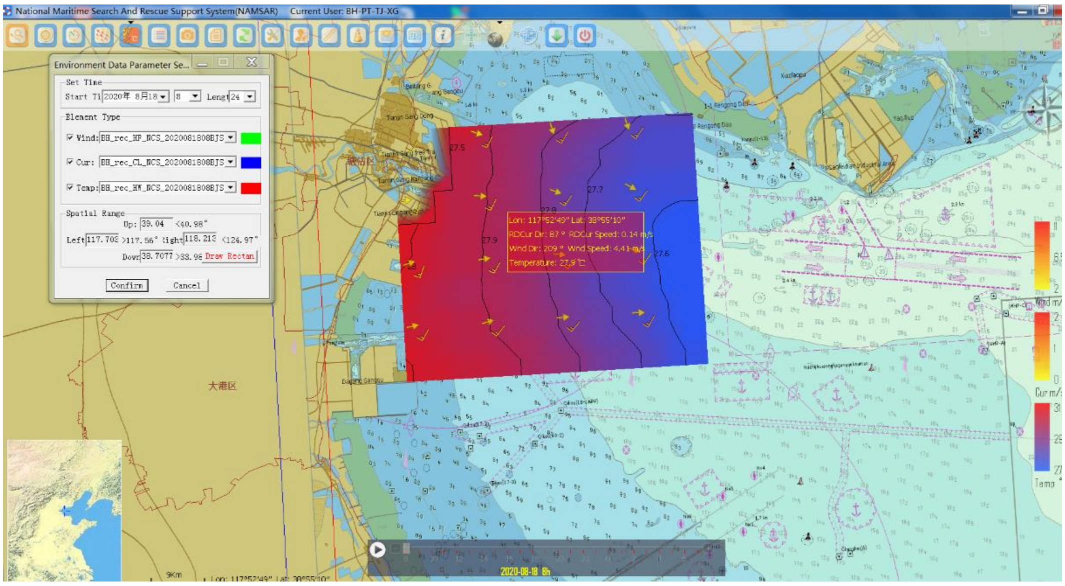

Figure 13: National maritime search and rescue support system

Source: Author

3.6 Challenges faced by decision support system

Judging from the data released by China Maritime SAR Center, AI equipment is gradually being applied to maritime search and rescue process. The formulation of search and rescue plans is changing from relying on manual search and rescue experience to depending on search and rescue decision-making algorithms. However, giving full play to the actual capabilities of search and rescue decision-making algorithms requires many simulation experiments and consumes enormous time and money.

The domestic research on maritime search and rescue assistance system started late, and the various data related to maritime supervision in the early stage were scattered in different platform systems. It is necessary to establish a data model driven by environmental parameters to simulate the search and rescue process. Several difficulties need to be overcome. First, the existing search and rescue assistance system relies on a single data, which is not enough to support the simulation of the search and rescue process. Second, the search and rescue environment is often complex and diverse, and changed rapidly. Existing auxiliary systems cannot input dynamic obstacle information and cannot complete accurate calculations. Third, the degree of visualization of search and rescue assistance is insufficient, and only the final search and rescue plan can be given, and the simulated rescue scene cannot be seen directly.

CHAPTER 4 Current System and Challenges of Emergency Management in Tianjin

4.1 Intelligent construction of Tianjin port

In recent years, China’s ports have become large-scale and specialized, providing opportunity for the application of “smart +” technology. With the maturity of big data and 5G, IoT, AI, and automation technologies, ports will also become a systematic ecosystem.

Tianjin Nanjiang Bulk Cargo ports, as is shown in Figure 14, is the main terminal for handling coal operations. The terminal has a total of 7 coal berths, of which berths number 07-10 belong to China Huaneng Coal Terminal Company; berths number 13-15 belong to Shenhua Co., Ltd. At present, Tianjin Port is gradually carrying out the construction of an automated green wharf, and the proportion of shore power used by operation ships and oil platform work ships in Nanjiang Port has reached 100%.

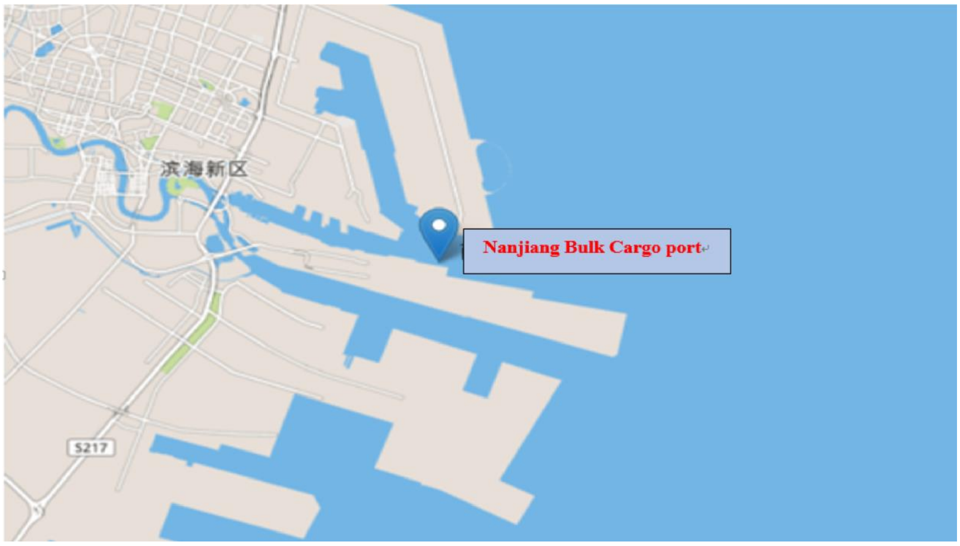

Figure 14: Location of Nanjiang Bulk Cargo Terminal
Source: Sea-web Ports

The Nanjiang Bulk Cargo Terminals have been transformed into automated ports in 2019. The automatic ports can realize remote operation of all work processes through the integrated visualization system, monitoring and early warning system, and emergency response system. The automated dock adopts a new type of automated ship loading system, which scans the hull through laser radar and then performs ship loading, realizing automatic ship loading under unmanned conditions. At the same time, the automation system can autonomously restrain and dispose of different dangerous actions, ensuring the safety of workers and improving the production efficiency of the bulk terminal.

However, we are also aware that the current intelligent transformation projects carried out by ports are mostly driven by the grassroots, cooperated with technology companies. The investment in AI lack strategic considerations by port operators and overall top-level design of the port group. The data required for the smart port is divided into different departments and platforms. However, the construction of smart ports will change the existence of departmental platforms, leading to conflicts of interest and even unemployment, which is one of the biggest obstacles in development.

4.2 The geographical and hydrological conditions in the SAR region of Tianjin

The Tianjin port is located in western of Bohai Sea. The land coast nearby Tianjin Port is flat and the water depth is shallow, which is the typical semi-closed harbor (Feng, 2006). After years of coastal construction projects such as wharf renovation and land reclamation, Tianjin Port has become the largest artificial harbor in China, with seven waterways in total, and the main waterway is capable of carrying 300,000 ton ships.

As is shown in Figure 15, the search and rescue region is consisting of 11 points of line A, B, C, D, E, F, G, H, I, J ,K , which is the same with the administration area of Tianjin MSA. The coastline is 150 kilometers and the sea area is 530 square kilometers.

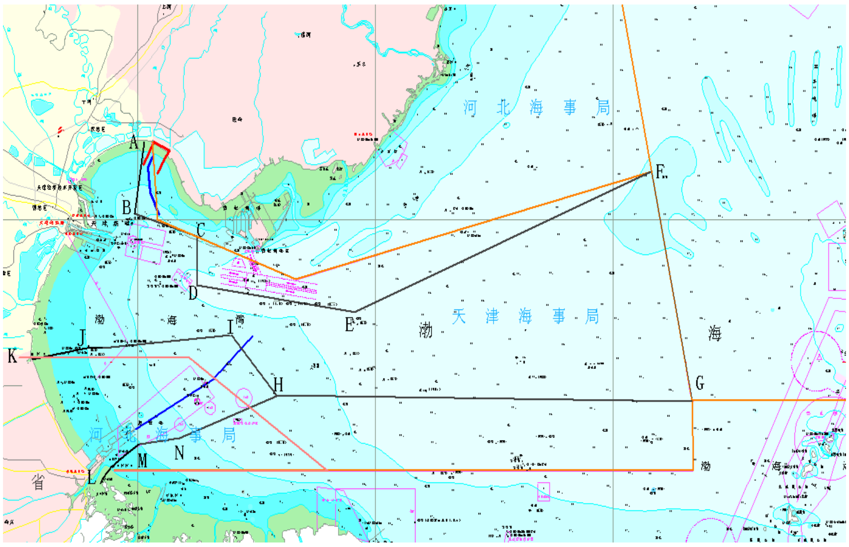

Figure 15: The search and rescue region of Tianjin
Source: Tianjin MSA

1) Temperature: The Tianjin sea area has a continental climate. The highest

temperature is in July and August, and the lowest in January. The average annual temperature is 12.0 ℃with16.1℃ as the highest average annual temperature and 8.7℃ as the lowest one.

2) Wind: The normal wind direction in this sea area is from northwest to northeast, and the northeast wind has the highest intensity. The strong winds above Beaufort 7 occur average 12 times a year and the average annual wind speed is 5.3 m/s. The southeast wind and southwest wind appear most in summer, and the northwest wind, northeast west wind and west wind dominate in winter. Sometimes typhoons often affect the waters from July to August. Occasionally, strong northeast winds occur, in which wind force above 7 account for 1% -7%. During the winter, the Bohai Sea often experiences strong winds, seriously endangering the safety of ships. Table 3 shows wind speed and direction frequency distribution in Tianjin port.

Table 3: Wind speed and direction frequency distribution

wind scale / direction rate	0. 3−5. 4 (m/s)	5. 5−7. 9 (m/s)	8. 0−10. 7 (m/s)	10. 8−13. 8 (m/s)	13. 9−17. 1 (m/s)	≥17. 2 (m/s)	total (m/s)
N	4. 10	0. 29	0. 09	0. 02			4. 51
NNE	2. 44	0. 13	0. 02				2. 58
NE	2. 71	0. 24	0. 11				3. 06
ENE	3. 18	0. 73	0. 37	0. 09	0. 02		4. 39
E	3. 86	1. 67	0. 86	0. 45	0. 06		6. 90
SSE	5. 03	1. 20	0. 41	0. 08	0. 01		6. 74
SE	5. 27	1. 29	0. 22	0. 01			6. 78
SSE	5. 19	0. 62	0. 10	0. 01			5. 92
S	6. 06	0. 57	0. 02				6. 65
SSW	6. 22	0. 34	0. 01				6. 57
SW	6. 50	0. 10	0. 01				6. 61
WSW	6. 56	0. 06					6. 62
W	8. 50	0. 05					8. 55
WNW	6. 81	0. 02					6. 83
NW	7. 27	0. 72	0. 06				8. 05
NNW	7. 34	1. 16	0. 17	0. 02			8. 69
C	0. 55						0. 55
total	87. 59	9. 19	2. 45	0. 68	0. 09		100. 00

3) Fog. In autumn and winter, inter alia, in October-January, there is dense fogs. The average annual number of foggy days is 14.8 days with 29 days as the maximum annual one and 15 days as the maximum monthly one.

4) Water depth. Mostly the average depth of the shallow sea is 20 meters.

5) Tide. This sea area belongs to the irregular semi-diurnal tide with uneven diurnal tide and significant low tide. According to statistical tide data over the years, the average sea level is 2.786m above the base level; the high tide level is 6.01m; the low tide level is -1.19m; the average low tide level is 1.35m; and the average high tide level is 3.97m.

6) Ice. The glacial period in this area lasts from November to March approximately, and it gradually freezes from north to south. The heavily glacial period is from January to mid-February and then gradually disappears.

4.3 Maritime risk factor in Tianjin

From 2013 to 2018, there were 106 ship traffic accidents in Tianjin Port and its adjacent waters. Among them, the most frequent ship traffic accidents were ship collisions. Ship traffic accidents frequently occur near the entrance and the branch of the main channel, affected by the dense traffic flow. The main causes of the above-mentioned ship traffic accidents are:

1) Human factors: Ship owners or management companies with safety management

responsibilities fail to perform their duties effectively, and fail to provide comprehensive technical guidance and shore-based support for the critical equipment failure of the ship;

2) The ship's factors: Machine failures and line aging cause contact damage and fire accidents because of the lack of daily maintenance for ships in time;

3) Special meteorological factors: such as heavy fog, hurricane, ice conditions, etc., which make the ship difficult to handle, resulting in ship traffic accidents;

4) Traffic factors: As is shown in Figure 16, the density of ships in the Bohai Bay has increased rapidly, the space for ship evasion and manipulation is getting smaller and smaller, and the probability of collisions between fishing vessels, sand transport ships and commercial vessels has increased significantly.

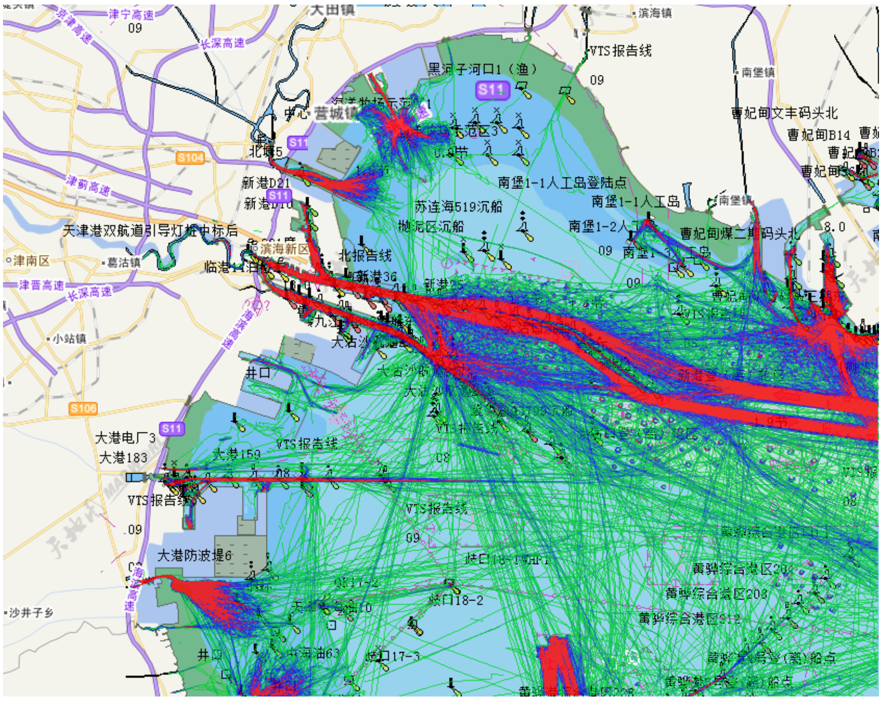

Figure 16: The density of ships in the Bohai Sea

Source: Tianjin MSA

5) At the same time, the illegal net cages are a variable factor. Net cages are an important infrastructure component in the marine aquaculture industry. However, many illegal net cages settings in the navigation area, affect the safety of ship's navigation seriously. At the same time, many boxes, equipped with AIS, intensified maritime identification signal, which has caused vast difficulties for maritime officials to supervise maritime information.

4.4 Challenges of emergency management in Tianjin

4.4.1 Challenges of emergency management department

The China Maritime Search and Rescue Center is located in the Ministry of Transport of China. Local search and rescue centers in coastal provinces are responsible for local maritime search and rescue services. The search and rescue operations at sea are mainly completed by the China Rescue and Salvage of Ministry of Transport, volunteers, and non-governmental organizations. In China, according to statistics, an average of dozens of people are lost in marine disasters every month. ("Ministry of Transport", 2019).

Table 4: SAR statistic of China in the last decade

Year	**Number of operations**	**Number of people in distress**	**Number of people rescued**	**Rate of Success (%)**
2009	1784	20280	19565	96.5

2010	1964	24513	18397	96.2
2011	2218	24513	23555	96.1
2012	2177	19352	18712	96.7
2013	1954	15757	15250	96.8
2014	2164	21397	20692	96.8
2015	2014	15926	15387	96.6
2016	1884	14698	13727	93.4
2017	2076	15853	15261	96.3
2018	2063	15046	14493	96.3

Source: China RCC

Table 4 shows the success rate of maritime search and rescue has maintained a relatively high level in China. According to Tianjin SAR statistics, from 2009 to 2018, Tianjin MRCC has organized 288 maritime search and rescue operations. It dispatched 905 rescue ships, assigned 35 rescue aircraft, rescuing 286 ships and 3908 people in distress, and the rescue rate was 97.69%, which is higher than most countries. But the actual emergency search and rescue capability is facing a great challenge due to the difference in statistical methods.

The Tianjin Maritime Search and Rescue Center is the competent department in charge of maritime emergency search and rescue in Tianjin. The Maritime Search and Rescue Center office is set up in the Tianjin MSA and is responsible for daily duty and danger disposal. The search and rescue center has 22 member units, covering the government agencies in charge of medical treatment, border defense, inspection and quarantine, customs, military and ports in Tianjin, as well as civil helicopter companies, oil spill handling companies, salvage and rescue companies and other social rescue assistance. At the same time, Tianjin has a professional maritime search and rescue support team. Volunteer team members include divers, doctors, crewmembers, helicopter pilots and other personnel with professional skills. Social forces have always been an important supplement to maritime emergency search and rescue resources. The organization of professional search and rescue skills training is needed to enhance the awareness of maritime emergency search and rescue in the whole society and strengthen self-rescue and mutual rescue capabilities.

The working principle of Tianjin's marine emergency search and rescue management is "people-oriented, government-led, unified command and combination of prevention and response". Tianjin Maritime Search and Rescue Center, as the coordination department of Tianjin Maritime Search and Rescue, lacks government financial support and social attention, leadership among the search and rescue member units and a strong command and coordination system. The existing maritime search and rescue volunteer teams cannot effectively participate in the maritime rescue operation, and there is a lack of professional training for the personnel of the search and rescue member units participating in the maritime search and rescue operation. Social forces have always been an important supplement to maritime emergency search and rescue resources. The organization of relevant training is required to raise the awareness of maritime emergency search and rescue across the society and strengthen self-rescue and mutual rescue capabilities. Limited by training funds and time cost, it is difficult for maritime emergency search and rescue training to be popularized by social forces, resulting in a large number of social forces unable to play a role in actual search and rescue operations.

4.4.2 Main problems on emergency management of Tianjin

"Tianjin's maritime search and rescue emergency plan" requires that to improve the efficiency of maritime emergency management, we need to comply with the strategy of CEM. Usually, in the mitigation titer, an effective competent organization department should be established to assess maritime risks and develop strategies to reduce maritime hazards. In the preparation titer, the search and rescue center should coordinate professional and other search and rescue resources, and establish early warning and prevention mechanisms. In the response titer, emergency response procedures should be established, search and rescue plans should be developed, search and rescue resource allocation and task coordination should be established. In the recovery titer, RAS center must always pay attention to the public attitude towards emergency events, analyze the costs and benefits of the search and rescue process, evaluate the search and rescue operation against previous search and rescue cases, and find out what can be improved. At present, the search and rescue management in Tianjin mainly faces the following shortcomings.

4.4.2.1 The deficiency of the management mechanism of maritime SAR

1) Tianjin is a port city, and the city's political center and financial center are far away from the port, so most citizens feel unfamiliar with the port waters. Maritime emergency work has rarely received the attention of senior government officials and the general public. Tianjin MSA, as the leading agency for search and rescue work, has insufficient leadership in search and rescue member units, and inter-governmental

relations are poor.

2) The personnel involved in maritime search and rescue operations in existing search and rescue member units lack professional training. Limited by training funds and time costs, it is difficult to popularize the maritime emergency search and rescue training by social forces, resulting in a large number of social forces unable to play a role in actual search and rescue operations.

3) Search and rescue operations rely too much on the experience of the search and rescue coordinator. The decision-making in the early stage depends on the experience of emergency search and rescue personnel because of the urgent time for maritime search and rescue emergency response, complicated information, complex communication and coordination departments and the limited available information in the initial stage. If the search and rescue coordinator makes a mistake, it will cause serious consequences.

4.4.2.2 The deficiency of the operation mechanism of maritime SAR

Maritime emergency management has the problem of “emphasis on emergency and light on prevention”. According to the theory of CEM, emergency management not only responds to the entire process of brewing, occurrence, response, and recovery of maritime emergency events in time series, but also includes effective management of disposal elements and risk elements at the micro-scale of each link.

1) In terms of early warning mechanism, emergency response is a kind of abnormal

management, which requires rapid response and is easier to attract attention. In the brewing stage of maritime emergencies, early warning work as a normalized management requires plentiful manpower and time, and is easily overlooked.

2) In terms of evaluation mechanism, the scientific evaluation mechanism needs to consider various impact factors, and it is still done through the experience and professional knowledge of search and rescue personnel in actual operations. In maritime emergency search and rescue operations, there are often situations in which a large amount of resources need to be invested in emergency search and rescue in a short time. How to quickly evaluate the rationality of search and rescue resource allocation, the effectiveness of search and rescue plans, and the profitability of search and rescue costs are tricky for emergency management.

3) In terms of compensation mechanism, life rescue at sea is a kind of gratuitous action. This is clearly stipulated in international conventions and domestic laws. Countries, institutions, ships, and facilities should provide assistance to anyone in distress at sea as long as they do not endanger themselves. At the same time, the high risk and high investment of maritime search and rescue are statutory obligations of governments and maritime vessels under international law. The lack of financial compensation often dampens the enthusiasm of social rescue efforts. This restricts the effective development of maritime emergency search and rescue in the jurisdiction. The government should also provide corresponding public services.

4.4.2.3 The deficiency of the guarantee mechanism of maritime SAR

1）The preventive patrol supervision is inadequate. Currently, maritime safety supervision mainly includes on-site patrol management and electronic patrol management. However, there are certain shortcomings in each supervision method. On-site patrol management requires a large number of patrol ships and maritime officers, and the cost of law enforcement is very high. Electronic patrol management can be achieved through an electronic patrol software system, which includes AIS, Closed Circuit Television Camera (CCTV), and drone video patrol. CCTV is the most widely used in electronic patrol. Maritime officers can monitor waters, ships and personnel through video 24 hours a day. However, the maintenance and management of these CCTV devices often fail to meet the requirements and cannot guarantee stable signal quality. Moreover, the monitoring and analysis of video signals also requires abundant labor costs.

Unmanned aerial vehicles that can monitor a large area of sea are ideal regulatory tools currently, but there are also shortcomings. First, the degree of intelligence of civilian drones cannot meet the needs of patrol supervision, and the task needs to be completed with manual assistance. Second, drone patrol work is limited to surveillance. Once dangerous situation or sea surface pollution are discovered, it is impossible to rescue or sample pollution in the first place. Third, the drone has limited battery life and cannot work for a long time, and it is impossible to supervise the sea areas far from the port.

The emergency management problem directly caused by insufficient preventive patrol supervision is the existence of blind spots in safety supervision. Some emergency dangers in the port area are difficult to detect and rescue in a timely manner, and some man-made pollution accidents cannot be discovered and obtained evidence in the first place, resulting in complicated and inconvenient follow-up disposal.

2) The deployment of emergency search and rescue forces is unreasonable. As is shown in Figure 17, the professional search and rescue agencies deployed at Tianjin Port and the surrounding Qinhuangdao Port are jointly equipped with 7 professional rescue ships. However, most of these professional ships are old, slow in speed, and have insufficient emergency search and rescue capabilities. For example, the Tianjin rescue base is only equipped with the small glass fiber reinforced plastic rescue boat “Huaying 387”, with a length of only 14.3 meters and a speed of 17 knots. It will not be able to take action in the face of emergency hazards in windy weather of Beaufort wind force 8. Professional rescue aircraft are deployed at Dalian Port and Penglai Port, which are far away from the waters of Tianjin, and it is impossible to rescue maritime dangers immediately.

Figure 17: Distribution of professional search and rescue resources

Source: North China Sea rescue Bureau

3) The integration of search and rescue resource information and management information is insufficient. In emergency operations, search and rescue ship resources, professional rescue equipment information, and search and rescue expert personnel information need to be integrated in a very short time. However, most of the professional emergency resources belong to different organizations and are scattered in different sea areas and coasts. These resources are also in dynamic change. Nevertheless, the time is urgent and the scope of emergency resources deployment is limited when marine emergency danger occurs. Therefore, the implementation of grasping the dynamic information of search and rescue resources and the targeted deployment of resources according to the location and characteristics of the dangerous situation is a topic of focus in emergency management.

CHAPTER 5 Proposal for Maritime Emergency Management in Tianjin

The current multi-level maritime search and rescue center system is the basis for ensuring the organization of maritime emergency management. The management concept of the search and rescue center needs to be matched with the regional economic development, and it should be moderately advanced and innovative. The planning and layout should be consistent with the development strategy of “building China’s strength in transportation” and the development trend of modern advanced technology. To improve the emergency management capabilities in Tianjin, we must do a top-level design, break the barriers between government agencies, rely on cutting-edge technology, and configure advanced technical equipment.

5.1 Top-level design

Emergency management is a public service provided by the government to the public. As the main provider of public services, the government bears the first responsibility. The Tianjin SRR is connected with Hebei, Liaoning and Shandong Province. Search and rescue work often requires coordination among different regions and the sharing of search and rescue resources, which largely determines the quality of the search and rescue outcome. The coordination of maritime emergency search and rescue management between Tianjin and neighboring provinces is a manifestation of intergovernmental relations. In China’s intergovernmental relations dealing with emergency management, the central government is relatively dominant and local governments support collaboration. The central government intervenes for the first time when a major maritime emergency disaster occurs. This structure both can effectively avoid the expansion and spread of emergencies and encourage local governments to actively invest in the construction of emergency prevention systems for emergencies and improve early warning and monitoring capabilities.

The cooperation of regional government departments will be difficult to maintain effectively if it is lack of authorization from higher-level departments in China's government hierarchy. Therefore, good cooperation in emergency situations must be based on the mutual trust established by long-term running-in under normal conditions.

The construction of a smart port in Tianjin Port provides the possibility to upgrade maritime emergency management. The all-weather monitoring of the terminal can realize real-time management of risk factors in the port area. Port operators and the national maritime emergency search and rescue center need to strengthen high-level cooperation, integrate emergency management theory into the construction of smart ports, and gradually realize smart emergency management with the construction of smart ports.

The construction of emergency management in Tianjin should emphasize top-level design, coordinate development with neighboring provinces, and realize cooperation in emergency management mechanisms. When dealing with maritime disasters, search and rescue agencies in neighboring provinces can be included in the emergency decision-making level, providing a multi-dimensional reference for emergency management, to realize the exchange and sharing of search and rescue resources. The search and rescue resources in different regions often change, and the need for a search and rescue resource may be huge, especially when oil spill-related disasters occur. If more search and rescue resource information can be grasped, more resources can be mobilized to achieve rapid and professional assistance.

How to achieve effective coordination between governments and how to master a large amount of search and rescue resource information? These two problems can be quickly realized through the application of AI technology. Using big data calculations, you can track the dynamics of search and rescue ships, aircraft, equipment and personnel. Managers are required to collect and summarize the above data in real time.

5.2 In-depth participation of social resource

At present, emergency management emphasizes the coordination operations of the search and rescue units of society and volunteers, considering the professional rescue source possessed by the government cannot fully and effectively complete the marine emergency search and rescue work. Western countries have encourage various social organizations and volunteer teams to actively participate in marine emergency search and rescue. This will not only reduce the need of the professional rescue resource, but also greatly improve the efficiency and success rate of emergency and save huge amount of costs. Government departments must establish and implement necessary education and training for social organizations and volunteers, and establish a certain reward and punishment system, aiming to improve the emergency skills and rescue experience of disaster participants.

The allocation of professional rescue resource for maritime emergency in the Tianjin area is in the face of conventional emergency events. In the scenario of more complicated situations, social resources often have better solutions. For example, in the world of unmanned patrol boats, the government has fallen behind and is just groping how to apply it in emergency management.

To the best of my knowledge, government departments can use long-term or short-term procurement of public service products from social forces to reduce high-cost and self-built equipment, which is manifested in the rental of equipment, products, and services. They can also take part in joint research on related topics, such as the explore to the role and application areas of unmanned ships in the supervision of marine emergency search and rescue cooperated by the Tianjin MSA, Liaoning MSA, Zhuhai MSA, Wuhan University of Technology, Shenyang Institute of Automation, Chinese Academy of Sciences and Zhuhai Yunzhou Intelligent Technology Co., Ltd..

5.3 The application scenario of AI in emergency management in Tianjin

Tianjin Maritime Search and Rescue Center has 6 sub-centers. In the early emergency response process of an emergency, the sub-centers coordinator who receives the alert will conduct the early treatment to deal with the emergency. However, due to the lack of risk assessment models in the early stage of actual operations, it is impossible to effectively assess maritime disasters, resulting in the inefficiency of emergency management. AI technology can play an important role in the whole-process of emergency management strategy, and significantly improve emergency management capabilities.

AI technology has been maturely applied in many fields. Technologies that can be used in emergency management include image recognition, big data, unmanned ships, UAV, intelligent robots, and deep learning. AI boats are highly mobile and can work 24 hours a day. They are suitable for daily cruise supervision, emergency response and safety assurance in coastal waters. The drone cannot be affected by the terrain and has a wide range of operations. Thus, it is suitable for conventional sea patrols, aerial search and transportation of emergency supplies. Intelligent robots can withstand risks such as fires, hazardous chemicals or deep-water operations, and are suitable for marine fire rescue, dangerous goods disaster rescue and underwater emergency operations. Image recognition technology can intelligently classify and label images and find out risk factors. It is an efficient way to assist patrols and warn and prevent marine emergencies. Big data technology can find specific information from massive amounts of information through targeted algorithms, which is suitable for database maintenance and update in emergency resource management. Deep learning technology gives computer a brain-like thinking mode. In the process of emergency response, deep learning can more comprehensively assess risk factors, combined with past accident cases, and assist search and rescue coordinators in formulating emergency strategies. Discuss the impact of AI on emergency management based on the time series in the CEM strategy.

5.3.1 Preparation stage

The quality of preparations directly affects the results of emergency management. In the preparation stage, maritime officials generally need to go through four steps: data collection, risk element analysis, safety hazard definition, and hazard rectification. Data collection is a complex project because the data is always dynamically changing. The risk elements also need to be analyzed manually by professionals. Faced with such a large amount of data content, the analysis results are prone to deviations, leading to undetected safety hazards, and finally an emergency accident.

5.3.1.1 Static data

A current problem that seriously affects the efficiency of emergency management is the coordination between different regions, including the lack of information sharing and information transmission speed between different governments departments. In the current top-down emergency organization structure in China, professional and social forces can be widely mobilized to participate in rescue in the face of high-level emergency accidents. Some dangerous situations that occur in the border area of responsibility require the command and coordination of higher-level search and rescue coordination center. Meanwhile, the search and rescue sub-centers are often responsible for receiving, assessing, and disposing of the danger in the initial stage of the danger. As a result, the disposal measures and the rescue resources that can be mobilized will be very limited. Maintaining communications between search and rescue departments and sharing search and rescue resources would have been an important means to improve the efficiency of emergency management originally, but these tasks take up enormous labor costs.

Marine ship information, cargo information, hydrological and meteorological information, port construction operation information, navigation environment information, search and rescue resource information (including equipment and materials to prevent oil pollution, professional divers who can participate in underwater rescue, and transportation professionals who are familiar with ship hull and marine dangerous goods) and other maritime-related data are distributed among different computer systems and government departments. To obtain rich data resources, it is necessary to break the barriers between government departments and share basic data that is not confidential. For example, due to the different construction times of the VTS systems of the maritime safety bureaus around the Bohai Sea, the manufacturers and models of equipment and systems are different, and it is very difficult to realize information sharing. The development of AI technology and the application of cloud storage technology can make information sharing and information communication simple and fast, thereby improving the efficiency of collaborative decision-making.

At the same time, in the face of these huge databases, it is impossible for humans to find out the connections behind various data and run massive data analysis. However, big data algorithms can use fuzzy correlation and full-sample thinking to propose solutions to problems found in massive data.

The automatic comparison and learning ability of AI can distinguish the differences from different dimensions and help the search and rescue decision-making system to better grasp marine environment elements.

5.3.1.2 Dynamic data

Maritime patrol is the process of inspecting maritime supervision targets, predicting and analyzing the security status and development trend of the targets, to identify potential risks and correct them. It is an important means to eliminate hidden accidents and prevent maritime emergencies. Usually maritime patrols are divided into boat patrols and electronic patrols. Traditional boat patrols require maritime officers drive maritime ships to conduct patrols in high-risk waters and require professionals to steer ships. Traditional electronic cruises use cameras, radar signals and AIS signals deployed on the dock to check the supervision targets one by one to determine whether there are potential safety hazards.

The AI unmanned ship can be used as a conventional cruise supervision method and can patrol all waters in the jurisdiction. The video and audio sensors installed on the unmanned ship will synchronize the collected information to maritime search and rescue centers at all levels. At the same time, the unmanned ship can also be equipped with water quality monitoring equipment to effectively monitor changes in the marine environment, prevent collisions or pollution risks and carry out forecast and warning accordingly. Unmanned ships also have the advantages of fast speed, short preparation time for sailing, and high adaptability to the operating environment. After receiving an emergency search and rescue task, the unmanned ship can quickly arrive at the scene in a short time. It can not only collect on-site distress information, but also carry out simple emergency search and rescue.

Electronic cruise mainly determines the risk of maritime targets by judging whether the signal is abnormal. However, it requires manual judgment and analysis for Closed

CCTV signals, which not only requires quite heavy work force, but also needs simultaneous monitoring of more than 150 video signals at the dock. Although this mode of work seems impossible to complete, the image recognition technology of AI provides the possibility for electronic cruise work. Image recognition software can classify and identify the targets in the video signal, and convert some risk scenarios into the starting conditions of the early warning model through preset parameters. Figure 18 shows the preliminary application of Augmented Reality technology, which provides basic ship information for electronic cruise. Once the AI finds these risk scenarios, it will issue an alarm to remind the electronic cruise staff. The powerful computing power of AI can support the system to simultaneously monitor multiple video signals and realize the real-time operation of electronic cruises. Theoretically , it can provide early warning of all risks in the waters near the port and improve the efficiency of emergency management.

Figure 18: Augmented Reality technology in electronic cruise

Source: Tianjin MSA

The popularization of AI applications provides important ideas for emergency management and prevention in the new era. The classification and labeling of image recognition can make electronic cruise work a reality. The information collection and automatic analysis of big data can improve the timely accuracy of information analysis and reduce the interference of human factors. As long as potential safety hazards are found, data reports will be automatically generated to warn of possible accident risks. In the future emergency management work, information collection capabilities will directly affect the emergency management level.

This article believes that the National Maritime Search and Rescue Center can design AI maritime emergency management application routes from the top. First, build a new AI unmanned ship platform at all levels of maritime search and rescue centers, and use unmanned ships with common technical interfaces, so that information sharing and intercommunication between multiple ships and across regions can be realized in the future. Second, explore to provide data interfaces to maritime search and rescue member units so that they can upload their own data. For example, the meteorological department can provide real-time and future weather conditions in the waters where the incident occurred. Only under a unified data platform can be guaranteed for the accuracy and effectiveness of data, and the communication and collaboration between administrative departments and participating agencies be smooth in cross-regional and cross-professional emergency search and rescue.

5.3.2 Process stage

Marine emergency search and rescue accidents mostly occur in bad weather, and the disposal process is costly, risky and professional. International conventions and Chinese laws and regulations have clearly stipulated that professional rescue assistance and passing ships should provide rescue in distress at sea under the condition of ensuring their own safety.

The search and rescue assistance system can realize decision-making assistance in the entire search and rescue process, which requires huge data support, including ship dynamic data, ship static data, marine environment data, and search and rescue resource data. The average annual AIS data of a ship will occupy nearly 28MB, and furthermore, the annual marine environment data of a region almost reaches 1.2 TB (Kim et al., 2020). A lot of calculations are involved in determining the best plan for the allocation of search and rescue forces. Similarly, significant changes in wind and flow can determine the probability maps for new datum lines or areas. The accuracy of the computations which can be done by the search planner without a computer are necessarily quite limited. Computer programs can be used to great advantage in relieving the search planner of much of the computational burden, allowing more computations of greater complexity to be done in less time with greater accuracy. It is usually difficult to process this large amount of data in a general computing system. Therefore, the big data framework is a good choice that can be used to calculate and formulate search and rescue plans.

In the process of organizing search and rescue operations, the search and rescue coordinator needs to consider the standardization of the emergency response procedures, the effectiveness of the search and rescue plan, the reasonability of the resource allocation and task coordination, and the cost of search and rescue to ensure the safety of personnel involved in the search and rescue operation.

The mature application of deep learning gives AI the ability of self-learning. In the emergency management process, AI can give the best results by learning past emergency management data, such as disaster relief knowledge in different professional fields, search and rescue cases, hull construction engineering, physical and chemical properties of ship cargo, marine meteorology, search and rescue plans, etc. At the same time, it can also allocate search and rescue forces based on the best search and rescue resources obtained from big data analysis. It can effectively improve emergency management decision-making ability, avoid empirical errors in manual decision-making and incomplete consideration problems.

The AI unmanned ship equipped with AI has the characteristics of unmanned on-site operation, which greatly reduces the risk of rescue personnel and can perform search and rescue missions in harsh marine environments. At present, the sensor equipment carried by unmanned ships includes infrared imaging and three-dimensional imaging. Lidar and sonar detectors can conduct detailed exploration of the scene of distress and search for people falling into the water. AI drones can deliver lifebuoys, medical supplies and other necessities according to the needs of those in distress.

5.3.3 Recovery stage

The maritime emergency search and rescue management preparation and execution phase enjoy great importance, but the recovery work is equally important. Marine disasters often have a huge impact on people’s psychology. Whether it is a man-made disaster or a natural one, it will arouse strong public opinion. Good public opinion guidance is also the focus of maritime emergency search and rescue management. For a long time, emergency management did not pay enough attention to the restoration of public opinion. News about disasters and the effectiveness of rescue efforts has been lagged behind. It is neglected to appease the public emotions and treat the public opinion positively.

With the continuous promotion and use of AI, human-computer interaction can be used to analyze the source of public opinion based on the computer technology and mathematical algorithms to realize the automatic analysis and classification of Internet public opinion AI. According to different classifications, personnel can concentrate on rumors with higher weights and accurately locate the wrong remarks in order to predict the direction of public opinion, formulate public opinion guidance strategies, actively respond to public queries, eliminate public opinion bias in emergency management, and improve the effectiveness of public opinion recovery in emergency management.

5.4 The application scenario of VR in emergency management

Emergency drills are effective measures to prevent disasters or reduce losses when accidents occur. However, traditional real exercises have many limitations: (1) on-site training is expensive with long preparation period, and it is difficult to repeat training in multiple times; (2) weather and emergencies cannot fully guarantee the exercise to achieve the intended purpose. It is difficult to realize the authenticity of complex dangerous scenes, and the closer to the real scene, the more difficult it is to control the risk of the operation; (3) the playback of emergencies in traditional exercise mode is mostly two-dimensional video mode, which cannot bring real situations to rescue drills; (4) conventional exercises are mostly based on scripted performance exercises, which are not effective and humane, cannot fully mobilize the enthusiasm of rescue personnel, and lack understanding of the overall rescue level and personal situation of the trained team.

The emergency command exercise system based on VR technology provides a new idea for search and rescue exercises. The application of VR technology to the field of emergency exercises has great advantages. First, the emergency command drill based on VR technology brings a sense of reality and immersive interactive experience to the trainees. It is a virtual simulation of reality and fictionalization of non-existent events, making participants construct virtual scenes. Conducting command in the middle brings users a sense of reality and immersion, which can maximize the effect of the exercise. Secondly, put the exercise into a virtually constructed scene can artificially set up emergencies according to the purpose of the exercise, where participants complete emergency command, search and rescue resource allocation and on-site command. And the exercise enjoys low average investment cost and high safety factor. It can fully mobilize the participants' enthusiasm for the exercise to demonstrate their physical and psychological changes at the real disaster site, and then explore the training method and intensity suitable for rescuers through data collection and analysis. In addition, this method of command can observe each search and rescue scene in real time, record the progress of the exercise, perform different types of search and rescue methods, judge the pros and cons of each method based on the simulation results and system evaluation, and optimize the search and rescue skills. According to the feedback, problems in the emergency response process are found, and the operability of the emergency plan is tested and evaluated.

The emergency command scene in VR needs to be built based on the actual marine environment. The marine weather and sea conditions must be changed based on the actual marine environment data. The ship parameters and crew configuration must conform to international regulations and ship type characteristics; the type of danger and evolution trend must conform to actual law; the type and distribution of emergency resources must conform to the reality; and the operating rules of the participants in the emergency command in the scene should be similar to the same as that in reality.

The VR emergency exercise system can provide participants with a first-view scene experience. Participants can choose different types of roles, such as search and rescue center, search and rescue coordinator, on-site commander, accident ship crew, rescue ship crew, rescue aircraft pilot, at the same time, the application of AI rescue equipment in emergency search and rescue provides a new perspective for VR exercises. UAV search, unmanned ship search, underwater robot search, AI smart equipment can provide autonomous search routes and rescue measures. Since there are fewer search and rescue application cases for AI smart devices in reality, exploring the application scenarios of AI device search and rescue can be expanded in the VR exercise system.

The VR emergency exercise system requires a large amount of search and rescue case data as the base for scene construction. Based on different types of danger, the exercise system needs to construct different virtual scenarios for ship fires, collisions, oil spills and grounding. In order to restore the realism of the dangerous scene to the greatest extent, the simulation of irregular fuzzy scenes such as sea water and flames may use a particle system. Make each particle in the system has its own attributes, including position, acceleration, life cycle, transparency, etc. The properties of the particles change over time to generate efficient real-time animation effects. In order to make participants get better feedback, the operating authority of the AI smart device will be opened to them. Participants can use the remote to control the route of the AI smart device and action instructions, such as releasing the lifebuoy, throwing a rope gun, and controlling the underwater robot to find people in the enclosed cabin and detect leaks on the hull. The feedback mechanism of the controller can transmit the collision, sound, flame and other information in the scene to the participants through tactile sense, visual sense, force, vibration and other sensory stimuli.

5.5 Application Cases of Artificial Intelligence Equipment in Maritime Emergency

The AI unmanned ship can complete different tasks. By carrying different task modules, it can replace manual search and rescue tasks in complex and dangerous waters.

5.5.1 The application of unmanned ships in an explosion accident

Late at night on August 12, 2015, the dangerous goods warehouse of Ruihai Company in Tianjin suddenly caught fire and exploded. This serious accident killed 165 people, hospitalized 798 people, and damaged 304 buildings and surrounding vehicle equipment, causing a total of RMB 6.866 billion in economic losses.

After this major accident, more than 100 kinds of chemical substances and secondary pollutants remaining in the explosion were analyzed. The surrounding environment caused various degrees of pollution with cyanide as the main pollutant. The secondary pollutants and scattered chemical substances generated by the explosion accumulated in the surface water along with firefighting water and rainwater, and some of the accumulated water may be discharged into the ocean through underground drainage pipes, doing harm to the marine environment and creatures. Monitoring the pollution of the waters near the drainage outlet became the focus of the emergency work of the Tianjin Maritime Administration at that time. Under such a highly polluted environment, the staff faced great safety risks when entering the site for sampling and testing. An unmanned ship company cooperated with Tianjin MSA used unmanned ships as a means of sampling seawater, which can sample and analyze water, and monitor 24-hour continuously through remote control. The two-month inspection ensured that the accident did not cause pollution to the marine environment.

5.5.2 The application of AI equipment in an emergency exercise

On August 30, 2018, Tianjin MSA organized the largest maritime search and rescue drill in Tianjin so far. The drill simulated a collision between a passenger ship and an oil tanker. The subjects of the exercise included ship firefighting, oil spill blockage, and personnel search and rescue. During the exercise, Tianjin MSA used multiple drones, multiple unmanned boats to build a combined sea and air joint search and rescue network, and used microwave communications and mobile network signals to achieve an all-round search and rescue coordination center on the scene of the accident. Surveillance provides support for search and rescue plans and coordination of search and rescue tasks. At the same time, the underwater robots carried by the unmanned ships completed underwater operations, finding the ship’s leaks and providing technical support for the subsequent plugging of oil leaks. This exercise is the first domestic application of large AI products such as unmanned boats, drones, and underwater robots in actual drill.

CHAPTER 6 Conclusions and Summary

Maritime emergency management, as an important responsibility of government authorities, is directly related to the safety of life at sea and the protection of the marine environment. IMO and the coastal countries have always focused on theoretical research and policy formulation of maritime emergency. Tianjin Port is an important port in northern China, facing huge maritime risks.

This dissertation demonstrated China's emergency management concept and introduced a Whole Process Model of Emergency Management. The institutional framework of Tianjin Port's maritime emergency management work was stated, and the problems faced by maritime emergency management work were analyzed in detail from the institutional and operational levels. This article tracked the application route of AI and VR technology particularly, analyzed the application status of AI and VR technology in business cases, such as smart ports and SAR decision-making systems that are being explored by countries all over the world, and reviewed experts' predict application prospects of AI and VR.

In the maritime emergency management process, increasingly mature unmanned ships, UAV, and AI robots can replace maritime officials to carry out maritime patrols, participate in maritime disaster relief, and perform dangerous tasks, such as sampling of dangerous goods and ship fire rescue. At the same time, the application of AI technology paths such as big data, image recognition, and depth algorithms can realize electronic cruises, which automatically identify and alarm risks at sea. In the face of maritime disasters, AI can provide search and rescue strategies that comply with the rules and logic, and comprehensively evaluate the on-site environment, search and rescue resources, search and rescue costs, and public opinion responses. VR technology is developing rapidly. The construction of virtual emergency search and rescue scenes will soon be realized in the future. Emergency manager can learn emergency management professional skills in the virtual scenes, experience the rescue process of various maritime disasters, and can also complete virtual emergency drill with other emergency management personnel.

Taking into account China's emergency management model, for the application of AI and VR in maritime emergency management, this paper proposes that the competent authority should conduct research and promotion from top to bottom, and cooperate with social resources to promote the application of AI and VR in emergency management.

There are still many difficulties and challenges in applying AI and VR technology to business cases and public management. Under the conditions of existing technology, the application cost of technology is still very huge. It is necessary for the competent authority to pay attention to technology trends, evaluate the cost-benefit ratio, and apply AI and VR technology to marine emergency management as soon as possible.

REFERENCES

Aznar, F., Sempere, M., Pujol, M.J., Rizo, R. & Pujol, M.J. (2014). Modelling oil-spill detection with swarm drones. Abstr. Appl. Anal. 2014.

Australian Air Force tests AI for search and rescue missions. (2019) http://cncc.bingj.com/cache.aspx.

Amisha, M. P and Pathania, M. (2019). Overview of artificial intelligence in medicine. J Family Med Prim Care 2019; 8:2328-2331.

Adams, L.M. (2008). Comprehensive vulnerability management: the road to effective disaster planning with the community. *Theor Construct Test 2008, 12(1):25-27.*

Aznar, F., Sempere, M., Pujol, M.J., Rizo, R., Pujol, M.J., 2014. Modelling oil-spill detection with swarm drones. *Abstr. Appl. Anal. 2014.*

Bogue, R. (2011). Robots for monitoring the environment. Ind. Robot an Int. J. 38 (6), 560–566.

Bagherian, M. and Alos, A. (2015). 3D UAV trajectory planning using evolutionary algorithms: A comparison study, Aeronautical Journal (2015), 119(1220):1271-1285.

Banda, O.A.V., Goerlandt, F., 2018. A STAMP-based approach for designing maritime safety management systems. Saf. Sci. 109, 109–129.

Chun, W. H., Papanikolopoulos, N. (2016). Robot Surveillance and Security. Springer International Publishing, 2016.

Chassignet, E.P. and Verron, J. (2006). Forecasting the Drift of Objects and Substances in the Ocean. *Ocean Weather Forecasting. 2006.*

Ding, Y., Li, Y., & Cheng, L. (2020). Application of internet of things and virtual reality technology in college physical education. *IEEE Access*, PP (99), 1-1.

Dong, S.H, You, X.X & Hu, F.X. (2020). Effects of wave forces on knotless polyethylene and chain-link wire netting panels for marine aquaculture cages. Ocean Engineering 207 (2020) 107368.Feng, S. (2006). Introduction to environmental ecological dynamics Of Bohai Sea. Beijing: *Science Press, 2006:26-27.*

Guo, X. L. & Mao, F.L. (2010). SARGIS: A GIS-Based Decision-making Support System for Maritime Search and Rescue. International Conference on E-business & E-govemment. IEEE, 2010.

Gao, S., Ai, B., Zhong, S., Liu, G.Y. & Xu, J.L. (2019). National maritime search and rescue support platform based on Service-Oriented Architecture. Mar. Forecasts 36 (3), 71–77.

Greenhill, A.E. 2019. A Primer of AI in Medicine. Techniques in Gastrointestinal

Endoscopy. Epub 2019.

Geng, L., Zhang, Y.　F. and Wang J. J. (2013). Cooperative Task Planning for Multiple Autonomous UAVs with Graph Representation and Genetic Algorithm, 2013 10th IEEE International Conference on Control and Automation. Hangzhou, China (2013): 394-399.

Huang, S. K, Lindell, M. K. & Prater, C. S. (2017). Multistage model of hurricane evacuation decision: Empirical study of hurricanes Katrina and Rita.［J］. *Natural Hazards review.2017,18(3) : 1-15*.

Hosseini, K.A., Jafari, M.K., Hosseini, M., Mansouri, B. & Hosseinioon, S. (2009). Development of urban planning guidelines for improving emergency response capacities in seismic areas of Iran. *Disasters 2009, 33(4):645-664. 10.1111/j.1467-7717.2008.01092.x*

Hu, X.X., Ma, H.W., Ye, Q.S. and Luo H. (2015). Hierarchical method of task assignment for multiple cooperating UAV teams, *Journal of Systems Engineering and Electronics (2015), 26(5):1000-1009.*

IAMSAR Manual. 1999. International aeronautical and maritime search and rescue manual. IMO/ICAO. London/Montreal, 1999.

IMO. (2004). GUIDELINES ON THE TREATMENT OF PERSONS RESCUED AT SEA. RESOLUTION MSC.167 (78)

Kong, Z.J. & Han, Q. L. (2015). The Research of Integrated Mobilization. *Journal of Beijing Institute of Technology.* DOI: 10. 15918/ J. Jbitss1009-3370. 2015. 0114.

Kong, Z.J. (2012). Research on National Economy Mobilization Chain. *Journal of Beijing Institute of Technology.* DOI：10.15918/j.jbitss1009-3370.2012.01.012.

Kratzke, T.M., Stone, L.D. & Frost, J.R. (2010). Search and Rescue Optimal Planning System, 2010 International Conference on Information Fusion. IEEE, pp. 1–8.

Kenta, U. (2020, March). Safer ships, safer crews, safer ports – thanks to artificial intelligence. https://blog.global.fujitsu.com/fgb/2020-03-11/safer-ships-safer-crews-safer-ports-thanks-to-artificial-intelligence/. Fujitsu.

Kasim, A. (2017). A comprehensive emergency management strategy for transportation systems in USA. *Transport problems.* 2017 Volume 12 Issue 4. DOI: 10.20858/tp.2017.12.4.15.

Kim, S.H., Roh, M., Oh, M., Park, S.W. & Kim, I. (2020) Estimation of ship operational efficiency from AIS data using big data technology. *International Journal of Naval Architecture and Ocean Engineering 12 (2020) 440e454.*

Liu, Y. K., Kong, Z. J. & Zhang, Q. (2019). Construction and Analysis of the Whole Process Model of Disaster Emergency Management. *Journal of Catastrophology*. DOI: 10. 3969 /j. ISSN. 1000 － 811X. 2019. 01. 036.

LeBerre, C., Sandborn, W.J. and Aridhi, S. (2020). Application of Artificial Intelligence to Gastroenterology and Hepatology. *Gastroenterology.* 2020; 158:76-94 e72.

Lindell, M.K., Prater, C.S. & Peacock, W.G. (2007). Organizational communication and decision making in hurricane emergencies. Natural Hazards Review, 2007; 8:50–60.

Laidlaw, P., Spennemann, D. and Allan, C. (2008). Protecting cultural assets from bushfires: a question of comprehensive planning. Disasters 2008, 32(1):66-81. 10.1111/j.1467-7717.2007.01027.

Li K. X., Yin J.B. and Fan L.X. (2014) Ship Safety Index. Transportation Research Part A, 66(2014), 75-87.

Ma, K.-C., Liu, L., Heidarsson, H.K. & Sukhatme, G.S. (2017). Data-Driven Learning and Planning for Environmental Sampling no. October.

Matos, A., Martins, A. & Dias, A. (2015). Multiple robot operations for maritime search and rescue in EURATHLON 2015 competition. IEEE, 2016, 978-1-4673-9724.

Mu, L., & Zhao, E. (2020). The Optimization of Maritime Search and Rescue Simulation System Based on CPS. *Big Data Analytics for Cyber-Physical Systems.*

Ministry of Transport in China. (2019). Statistical Information on Maritime Emergencies in China. http://zizhan.mot.gov.cn/sj2019/soujiuzx/.

Ramesh, A.N., Kambhampati, C. and Monson, J.R.2004. Artificial intelligence in medicine. Ann R COLL SURG ENGL 2004; 86:334-338.

Pashna, M., Yusof, R., Ismail,Z.H., Namerikawa, T.& Yazdani,S. (2020). Autonomous multi-robot tracking system for oil spills on sea surface based on hybrid fuzzy distribution and potential field approach. *Ocean Engineering, 207.*

Srinivasan, S., Dattagupta, S., Kulkarni, P. & Ramamritham, K. (2012). A survey of sensory data boundary estimation, covering and tracking techniques using collaborating sensors. Pervasive Mob. COMPUT. 8 (3), 358–375.

Vidan, P., Hasanspahic, N. & Grbic, T. (2016). Comparative analysis of renowned software for search and rescue operations. NAS MORE: ZNANSTVENI ASOPIS ZA MORE IPOMORSTVO 63 (2), 73–80.

Wang, Y. (2015). Aquatic Environment Monitoring Using Robotic Sensor Networks.

Wang, Y., Tan, R., Xing, G.L., Wang, J X. Tan, X.B., Liu, X.M. & Chang, X.M. (2016). Monitoring Aquatic Debris Using Smartphone-Based Robots. DOI: 10.1109/TMC.2015.2460240.

Wu, B., Zong, L., Yan, X. & Soares, C.G., 2018. Incorporating evidential reasoning and TOPSIS into group decision-making under uncertainty for handling ship without command. Ocean Eng. 164, 590–603.

Wu, B., Yip, T.L., Yan, X. & Soares, C.G. (2019). Fuzzy logic based approach for ship-bridge collision alert system. Ocean Eng. 187, 106152.

Xiong, W. T., Gelder, V. and Yang, K.W. (2020). A decision support method for design and operationalization of search and rescue in maritime emergency. *Ocean Engineering 207 (2020) 107399.*

Yang, T., Jiang, Z., Dong, J., Feng, H., & Yang, C. (2018). Multi Agents to Search and Rescue Based on Group Intelligent Algorithm and Edge Computing.

Zlatanova, S. and Fabbri, A.G. (2009). Geo-ICT for Risk and Disaster Management. Importance of Geo-ICT in risk and disaster management. *Geo Journal Library. Geospatial Technology and the Role of Location in Science. 2009.*

Zhou, R. (2020). Research on information management based on image recognition and virtual reality. *IEEE Access, PP* (99), 1-1.

Zhang, H.B. & Tong, X. (2016). Structural change in china's emergency management: theoretical generalizations. Social Sciences in China. 77-98. doi.org/10.1080/02529203.2016.1162010.